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ASTRONOMY WITH THE SMALL CAMERA.

H. C. WILSON.

In my first article on this subject (page 26) I spoke of photographing star trails as a pleasing and useful pastime for the amateur. We are able this month to present an illustration of this work. The upper picture of the frontispiece to this number of POPULAR ASTRONOMY presents a reproduction of a photograph of the north polar region of the sky, taken at Goodsell Observatory on the night of Sept. 14, 1893. The exposure was of just an hour's duration, with a stationary camera of 2½-inches aperture. The camera was directed as nearly as possible toward the true pole of the heavens and it will be noticed at once that there are a few faint stars very near the pole but none exactly at that point. The shortest trail is perhaps three times as long as it is broad. As you go away from the pole the trails of the stars increase in length, but each one is exactly one twenty-fourth part of a circle having the pole for its center. There are many more stars on this plate than can be seen with the naked eye. The brighter stars may be recognized by the thickness of their trails, and we have marked a few of the Greek letters, by which they are known, on the plate. The so-called pole star Polaris, or α Ursæ Minoris, it will readily be seen, is not at the pole but quite a little distance from it. The *Nautical Almanac* gives, its polar distance on Sept. 14 as $1^\circ\ 15'\ 40''$. To the left and above the pole is the wide pair of stars δ and at an equal distance farther to the left ε. These three form the tail of the Little Bear or handle of the Little Dipper as the constellation is sometimes called. Near the upper right hand corner of the plate is a very long trail which is really composed of two trails end to end, the two stars having the same declination but differing about an hour in right ascension. In reproducing this picture the original has been copied through a screen, so that the trails are all broken up by the meshes of the screen, but in the original negative they are perfectly smooth and uniform in width.

The second picture of the frontispiece was intended as a companion to the first, showing the appearance of the same stars when the camera is moved by clock-work. The direction of the camera was, however, changed so as to take in the whole constellation of Ursa Minor. The exposure was made of the same duration, the camera being attached to the 8-¼inch equatorial telescope. The observer corrected the irregularities of the driving clock every ten minutes, by looking through the telescope at the star ε Ursa Minoris and adjusting it to the cross-wires of the telescope. The night was not so clear as the one on which the trails were photographed, so that not so many more stars appear in the picture as might have been expected. Nearly all of the minute white spots on the plate represent actual stars. A few are flaws which in most cases may be recognized by their irregular outline when examined with a microscope. We have marked the principal stars with the Greek letters so that the reader will have no trouble in identifying them. The scale of this picture is about twice that of Klein's Atlas and a little greater than that of Heis' Atlas. It will be a good exercise for the student to see how many of the stars shown in this photograph can be identified in the sky with an opera-glass.

CONSTELLATION STUDY.

WINSLOW UPTON.*

II.

In the preceding article of this series, attention was called to the place which a study of the constellations occupies in the science of astronomy. It was stated that astronomers use the constellations to a very limited extent, simply referring to them in star catalogues and maps for the purpose of naming stellar areas within which the stars are situated. It was also stated that it is useful as well as interesting for any one to learn the leading configurations, because such knowledge gives a clearer idea of the effect of the Earth's daily rotation on its axis, and annual revolution about the Sun, than is otherwise obtained. But herein lies the chief difficulty in studying the groups, for they are not found in the same part of the sky at different hours of the night, nor at the same hour on different nights of the year. More than that, as the apparent rotation of the heavens each night is not in the

* Director Ladd Observatory, Brown University, Providence, R. I.

same plane as that on which we seem to be standing, the stellar groups are turned at different angles to the horizon, which materially adds to the difficulty of recognizing them. Groups which rise in the southeast and set in the southwest, like Scorpio and Canis Major as seen in northern latitudes, are affected but little, and so are always recognized when once they are known; but those which rise in the east or northeast, and set in the west or northwest, like Andromeda and Bootes as seen in northern latitudes, are so much affected that the casual observer sometimes fails to recognize that they are the same. And in the case of groups which rise in the northeast the difficulty is increased by the fact that they pass nearly overhead as they move towards the northwest. As no one likes to observe an object when near the zenith, the gradual change in the apparent position of the group is not noted, and there seems to be an abrupt change in its position in the northeast, and later in the northwest. In these northern latitudes the stars which are nearer the pole than the place of observation is north of the equator in latitude do not rise and set, but revolve about the celestial pole, always remaining above the horizon. They therefore appear in all possible positions as is readily seen by watching during one night the movements of the familiar "Dipper" (which is not a recognized constellation, but a part of the large constellation, Ursa Major), and repeating the observation during a night six months later.

The effect of the Earth's annual revolution about the Sun is suggested in the last sentence. As the Earth moves eastward about the Sun, an observer on the Earth sees the Sun projected upon the opposite side of the sky and moving in the same direction of rotation among the stars. Long before it was known that the Earth revolved around the Sun, it was observed that the Sun moved among the stars in an easterly direction nearly 1° a day, and it was very naturally supposed that this apparent movement of the Sun was real, and that the Sun actually did revolve around the Earth. Since the brightness of the Sun prevents us from seeing his movement among the stars, as we can do in the case of the Moon, we detect it by noticing where the same stars are on successive evenings at the same time. The constellations which are in the west at 8 o'clock to-night will be nearer the horizon to-morrow night at the same time, and in a few weeks will be lost in the Sun's brightness. A few weeks later the same stars will rise in the morning before the Sun, showing that the Sun has passed by them moving easterly. Or the same thing may be observed in any other part of the sky. The stars cross

the meridian four minutes earlier each night than the preceding night, and those which rise and set, rise and set four minutes earlier for the same reason. The effect of the annual motion of the Earth around the Sun is then to make the constellations appear in different parts of the sky at the same hour in different months of the year. It does slowly in a year what the Earth's axial rotation does each twenty-four hours.

It is worth emphasizing that the change in the constellations due to the daily and annual motion of the Earth is simply one of position in the sky but does not effect their relations to each other. Like the subdivisions of a country, each state has its neighboring states occupying the same relation to it. The same figure may apply too to the individual stars in the constellation, which like the towns of a state retain their relative positions. The figure fails only in the fact that individual stars have movements of their own, but on account of their enormous distances these motions can be detected only with the most refined instruments of modern astronomy, and are quite inappreciable in constellation study. If Abraham, or any other of the Chaldean sages, should look at the heavens to-day, he would notice the same constellations which he saw so many centuries ago.

It follows from the above that the constellations should be learned independent of the time of night and the season of the year. It may be well to begin their study by following the guide of some treatise which says that "at 8 P. M. in October, such and such constellations are overhead, due south, in the east," etc., but when once found, they should be learned with reference to each other, and should be watched at occasional times as long as they are visible in the evening hours, so that they will be recognized ever after whenever they are seen.

Only a passing reference needs to be made to a plan for studying the constellations which was suggested, though perhaps not seriously, many years ago. The names of the constellations were included in doggerel rhymes which one could commit to memory to aid in their recollection. Thus Dr. Watts is said to have treated the zodiacal constellations as follows:

> "The *Ram*, the *Bull*, the heavenly *Twins*,
> And next the *Crab*, the *Lion* shines,
> The *Virgin* and the *Scales*;
> The *Scorpion*, *Archer* and *Sea-Goat*,
> The *Man* that holds the *Water-Pot*,
> And *Fish*, with glittering tails."*

* Burritt's Geography of the Heavens.

And the constellations in the vicinity of Orion are embalmed in the following classic strain:

> "The *River's* shining streams beneath him pour,
> And angry *Taurus* rages close before;
> Behind him *Procyon* barks, and Sirius growls,
> While full in front, the monster *Cetus* howls."*

The essential condition for a satisfactory study of the constellations is that the several groups shall be learned without regard to terrestrial objects or to the time of day or year. To know a constellation only when it is over a particular tree is rather awkward in case the tree should be cut down, and it is only a little less foolish to recognize a group when in a particular part of the sky and not wherever the constellation may be found. The remedy for this difficulty is surely to learn the constellations independent of all terrestrial relations and solely by their relative positions. This can be done systematically in some such way as will now be given. It is recommended—

1. That the heavens be divided into four sections, each lune shaped with an angle of 90°,—(just as an orange is peeled into four divisions of this shape.)

2. That these four divisions accord with the system used by astronomers in designating stars by their right ascension and declination.

3. That the boundary lines between the divisions be traced among the stars, and also the celestial equator and ecliptic for reference lines.

4. That the zodiacal consetllations be first learned, and then the other constellations in each of the four divisions.

In northern latitudes, it is advisable to modify this general scheme by taking out of each quarter section the constellations which are north of the zenith, and forming a fifth division of polar constellations.

The first two of these recommendations require explanation for those who are unacquainted with the technical terms there used.

The system of latitude and longitude by which positions on the earth's surface are conveniently designated is familiar to every one. It is constructed in this way: 1st, a great circle on the sphere is drawn. In general, any great circle (a great circle is one whose plane passes through the centre of the globe) may be chosen, but usually some condition will determine its selection. In the latitude-longitude system, the condition is that the great

* Burritt's Geography of the Heavens.

circle shall be perpendicular to the earth's axis of rotation. 2d, a series of circles perpendicular to this circle are drawn, which in the latitude-longitude system are called meridians. They necessarily intersect at the poles and are of indefinite number. 3rd, one of these circles or meridians is selected as a Reference Circle,—in the latitude-longitude system that passing through some place, as Greenwich, is arbitrarily selected. The position of a point on the earth's surface is given by the distance from the equator to the point, measured upon the meridian of that point—its latitude—and by the angle between this meridian and the Reference Meridian—its longitude. In a precisely similar way the positions of the several stars are recorded. There are in fact three or four systems in current use, each having its special uses, but we are concerned now with only one, which corresponds with that of terrestial latitude and longitude in everything but the names employed. We usually look down upon a globe from the outside, and imagine the equator and meridians drawn upon the convex spherical surface. But in studying the stars we must remember that we are within the celestial sphere, and are looking towards the concave spherical surface upon which we may imagine the circles to be drawn. If the earth's axis were prolonged indefinitely, it would seem to pierce the sky at two opposite points, one of which is very near the star often called the Pole Star, or Polaris, and the other invisible in northern latitudes, but as much depressed below the south horizon as the north pole is elevated above it. In passing, it is of interest to note that the celestial pole is at precisely the same height above the observer's horizon as his latitude, and the latitudes of places on the earth's surface are found by measuring indirectly that height. If the plane of the earth's equator is imagined extended until it reaches the sky, it will trace thereon a circle at whose centre we seem to be situated. This circle, the celestial equator, always cuts the horizon at the east and west points exactly, and at its highest point, over the south point of the horizon in northern latitudes, is as high above the horizon as the difference between 90° and the observer's latitude. We therefore see but half of the celestial equator. It always occupies the same position in the sky, and the stars as they move across the sky describe circles which either coincide with it or are parallel with it. The Sun's daily path is upon the equator at the time of the vernal and autumnal equinoxes. The paths of different stars are circles, parallel with it, but smaller and smaller as stars are selected nearer the pole, like the parallels of latitude upon the terrestrial globe.

The circles which are perpendicular to the celestial equator, corresponding with meridians upon the globe, may now be imagined all intersecting at the celestial pole. But they are not called celestial meridians. The term meridian is reserved for the special one which passes through the point directly overhead and consequently through the north and south points of the horizon. The general name for them is declination circles or hour circles and declination corresponds with latitude on the Earth, as the distance from the celestial equator to the star measured upon its declination circle. Two of the declination circles have special names, that which passes through the two points of the equator where the Sun crosses it in March and September each year, called the Equinoctial Colure, and that which passes through the highest northern and lowest southern point which the Sun reaches in June and December respectively, called the Solstitial Colure. These colures are exactly 90° apart.

It will be profitable to notice here the effect which the daily movement of the heavens has upon this imaginary system of circles. The meridian has just been defined as the declination circle which passes through the point directly over the head of the observer—his zenith—and also through the north and south points of the horizon. It therefore seems to be an immovable circle, and is immovable as far as the observer's station is concerned. It is the trace in the sky of the meridian on the Earth which is drawn through the place of observation. By the diurnal motion of the heavens the various declination circles in turn coincide with the celestial meridian, and all the stars upon a given declination circle "cross the meridian" at the instant of the coincidence of the two declination circles. Another way of expressing the same idea is to omit altogether the idea of a fixed meridian and to say that each of the declination circles of the celestial sphere passes in turn directly through the zenith of any observer, and at that instant it is called the celestial meridian because it is in the plane of the observer's terrestial meridian. It follows from this that any region of the sky, for instance one of the four divisions suggested above, or any special constellation within it, may sometimes be wholly east of the meridian, or west of it, or intersected by the meridian according to the position of the declination circles bounding it at the given time.

It remains to speak of that which corresponds to longitude on the Earth and to the reference meridian, by which it is determined. The latter is arbitrarily chosen; on the Earth that of Greenwich we usually say is agreed upon. There is however no universal

agreement among civilized nations on this point, but astronomers of all nations have agreed to adopt the point on the equator where the Sun crosses it each spring as the reference point in the stellar system, and the declination circle passing through it, the equinoctial colure, is therefore the reference circle. The angle between this circle and the declination circle passing through any star is called the right ascension of the star, corresponding therefore with terrestrial longitude. It will be evident that the diurnal motion does not change the right ascension of the star nor its declination, because they are determined by fixed circles in the heavens which turn with it. Right ascension is always reckoned towards the east completely around the sphere and not like longitude on the Earth, both east and west from the primary meridian. It is usually expressed in time, that is hours, minutes and seconds. Declination is reckoned like latitude from the equator towards either the north or south pole, called north and south declination, or + and — declination, respectively. It is always expressed in degrees, minutes and seconds.

We are now ready to consider the first two recommendations for a systematic study of the constellations. The equinoctial and solstitial colures divide the sky into four grand divisions, each 90° or 6^h in width in right ascension, and extending from pole to pole. The division corresponds with the four divisions which might be made on the Earth between the meridian of Greenwich, and those 90°, 180° and 270° east of it.

The Sun crosses the celestial equator in the spring and at that time its right ascension is 0^h. Three months later he has reached the summer solstice, having passed through the first of the four divisions; in the next three months he traverses the second division and so on through the year. The evening sky shows constellations which are in general 60° to 240° east of the Sun, less than this south of the equator and more than this north of it, until in the vicinity of the pole all stars are above the horizon whatever their right ascension. After the autumnal equinox the Sun is in the third division of the heavens until the winter solstice is reached. During these months the fourth division lies west of the meridian and the first division east of it in the early evening.

Let us now carry our thoughts out of doors and try to get a clear idea of the four divisions of the sky, their bounding colures and the celestial equator. Facing the north (assuming that the reader is in north latitude) the "Dipper" and the pole star are first found. In the autumn the Dipper lies northwest of the meridian in the early evening, but it can readily be found whatever

its position, as the "seven stars" are so conspicuous. The two stars which form the side of the bowl opposite the handle are nearly in line with the pole star, a bright star rather isolated. They are sometimes called the Pointers from this fact. It will be noticed that the fourth star at the junction of the handle and bowl, is fainter than the others. The equinoctial colure passes very near this star, which is lettered δ Ursæ Majoris and was formerly called Megrez. Imagine the colure to start at the pole star and to run through δ Ursæ Majoris and continue in the same direction to the celestial equator; it will pass through the autumnal equinox. If continued to the south pole it will form the half of the colure which marks 180° or 12^h of right ascension. Near the autumnal equinox itself there is a star, η Virginis, and the circle passes near α Corvi and α Crucis, as will be mentioned later in taking up the constellations in detail. If we prolong the circle in the other direction, we shall find its position marked by three bright stars. The first is in Cassiopeia in the foot of the chair-shaped figure, and is about as far from the pole star as δ Ursæ Majoris. It is lettered β Cassiopeiæ and was formerly called Caph. Continuing the same line, two more stars are reached which form the eastern side of a large quadrilateral, the square of Pegasus. The stars are α Andromedæ and γ Pegasi, and were formerly known as Alpheratz and Algenib respectively. If the line is prolonged beyond the last named star as far as it is itself south of α Andromedæ, the vernal equinox is reached, in a part of the sky where are no bright stars. The five stars thus named mark the equinoctial colure with sufficient precision for the purpose at hand. It may help to recognize different orders of brightness to note that δ Ursæ Majoris and γ Pegasi are third magnitude stars, and the others, α Ursæ Minoris, β Cassiopeiæ, and α Andromedæ are second magnitude stars. δ Ursæ Majoris is about 32° from the pole, and β Cassiopeiæ a little less; α Andromedæ is 30° from β Cassiopeiæ, and γ Pegasi 14° from α Andromedæ. The "pointers" of the Dipper are 5° apart and the northern one is 28° from the pole.

The autumn evenings are specially good for tracing the equinoctial colure, as above described. The vernal equinox is then between the east horizon and the meridian, and the line of bright stars leading to it from the poles is in good position to be viewed. With this colure marked out so prominently in the sky, it is easy to imagine the solstitial colure drawn at right angles to it, but it does not pass near any very conspicuous stars. The 90° or 6^h half passes near η Geminorum which will be later referred to as

marking the summer solstice, and passes 4° east of α Orionis, the bright red star in the shoulder of that figure. The 270° or 18^h half passes through the head of Draco, and also near μ Sagittarii which marks the winter solstice.

The position of the celestial equator needs no line of stars to mark it, as it always passes through the east and west points of the horizon and crosses the meridian at a height which is the complement of the observer's latitude. The following, however, mark its position and are here given for future reference when the constellations to which they belong are discussed: The celestial equator passes through the Belt of Orion, 2° south of α Canis Minoris (Procyon), and near η Virginis, γ Virginis and α Aquarii.

The tracing of the ecliptic, which was suggested under the third recommendation, can best be done in connection with the study of the zodiacal constellations, which will be deferred to another paper.

The student of the constellations should learn the Greek alphabet (the small letters only are sufficient) if he wishes to designate the leading stars by their usual names. It was mentioned in the former paper that the usual way of naming the brighter stars is by the Greek letters given by Bayer in the seventeenth century followed by the Latin name of the constellation in the genitive or possessive case. Individual names are nearly obsolete except for the very brightest stars. In these articles both designations will usually be given.

In closing this paper it may be well to suggest that constellation study cannot be carried on successfully by reading, but that there must be constant reference to the heavens. As far as we have gone, we have examined the sky in a general way, divided it into grand divisions and noted the effect of the diurnal and annual motions upon the constellations. This effect will be more evident after a few constellations have been learned, but it is well at this very point to get a general idea of these motions. Let the reader answer the following questions: Do the stars which rise due east pass near the zenith? If not, how far from the zenith are they when they cross the meridian? How many of the stars of the Dipper are always above the horizon? It is a good plan to select a few conspicuous stars in different parts of the sky and watch their movements from night to night for several months; for instance the Pleiades, which in the autumn evenings are in the eastern sky, or the dog star Sirius, which rises in the southeast several hours after the Pleiades. The Dipper and the chair-shaped figure in Cassiopeia are good groups for this purpose in the

northern sky. The bright star α Lyræ or Vega, which passes nearly through the zenith as seen in the United States, and in October is west of the meridian in the early evening, is an excellent star to show how far north of the west point a star so situated sets.

The following is a list of the constellations which are visible in northern latitudes, and which will be referred to in the subsequent papers of this series. They embrace the fifty-seven constellations adopted by Argelander and are here arranged according to the four divisions of the sky explained above. The polar constellations are taken out of each division and placed by themselves. The other constellations are arranged in each division from the north toward the south. The zodiacal constellations are in italics; the Roman numerals I, II, III, and IV, refer to the four divisions of the sky bounded by the equinoctial and solstitial colures, and extending from 0^h to 6^h, 6^h to 12^h, 12^h to 18^h, and 18^h to 0^h respectively. An asterisk designates the constellations which are in Ptolemy's list. He also gives two others, Corona Australis and Ara, which are in the southern sky.

CONSTELLATIONS VISIBLE IN NORTHERN LATITUDES.

Constellations North of Zenith.

I *Cassiopeia, Camelopardalis
II *Ursa Major
III *Ursa Minor
IV *Draco, *Cepheus

Constellations of South Zenith.

I.	II.	III.	IV.
*Andromeda	Lynx	Coma Berenicis	*Lyra
*Triangulum	Leo Minor	Canes Venatici	*Cygnus
*Perseus	*Gemini*	*Bootes	Lacerta
*Auriga	*Cancer*	*Hercules	*Aquila and Antinous
Pisces	*Leo*	*Corona Borealis	*Sagitta
Aries	Monoceros	*Ophiuchus	Vulpecula
Taurus	*Canis Minor	*Serpens	*Delphinus
*Cetus	Sextans	*Virgo*	*Equuleus
*Eridanus	*Hydra	*Libra*	*Pegasus
*Orion	*Crater	*Scorpio*	Scutum Sobieski
*Lepus	*Canis Major	*Corvus	*Sagittarius*
Columba	*Argus	*Centaurus	*Capricornus*
		*Lupus	*Aquarius*
			*Piscis Australis

From world to world his couriers fly,
Thought winged and shod with fire:
The angel of the stormy sky
Rides down the sunken wire.

—*Whittier.*

TIME AND TIME SIGNALS.

CHARLOTTE R. WILLARD.

From the days when slaves sat under the open heavens watching the movements of the constellations that they might keep a record of time for their masters, or the monk counted the passing hours by repeating Psalms, or the more ingenious man measured his time by the burning out of a candle,—all the way down through the days of noon marks on the kitchen floor and the calling of gatherings at "early candle light,"—do we find men striving to answer the now familiar question, "What time is it?" These laborious efforts, with their varying measure of failure and success, seem to have come to almost perfect fruitage in an age which computes time to the hundredth part of a second, and in which a clock must be regulated to the tenth of a second if it is to hold any place as a standard time piece.

The observatory method of determining time is very simple in principle. The observer turns to his catalogue of stars, and chooses one for his observation, the catalogue giving him the time (to the hundredth of a second) at which that star will be on his meridian; he then turns to the telescope, and at the instant the star crosses the meridian records the time indicated by his clock. The catalogue gives the true time of passage, and unless the clock gives the same it is in error.

This method of clock testing might come into universal use were it not for two practical difficulties. First, the difficulty of determining when a star is on the meridian. Let the attempt be made on any clear night to determine the exact instant when a star passes the meridian, and the difficulty will be obvious—clearly so if it be remembered that the instant of passage must be named with extreme accuracy. This were indeed an easy matter if there were actual meridian lines drawn across the heavens as we see them on spheres; we should then watch the star as it rose in the east, and continued its westward way until the instant that it passed behind the meridian line. Just this effect *is* secured by the Observatory instrument used in making time observations.

The conspicuous part of a meridian circle is a telescope so mounted that it can be turned to any point on the meridian from northern horizon to southern, but cannot be turned upon any other part of the sky. Just back of the eyepiece of this telescope is placed a series of fine wires, one of which is coincident with the

observer's meridian. In observing, these wires seem to be projected as lines upon the sky, and the stars are seen passing behind them; the observer records the clock time of these passages, and has the desired data.

The second practical difficulty in the way of a universal use of this method of clock correcting is that of accurately recording the time. The observatory meets this difficulty by the aid of the chronograph. The chronograph presents a revolving cylinder about which a sheet of paper is clamped; a fountain pen rests upon the sheet, tracing a line as the cylinder revolves; an electric connection with a clock causes the pen to make a break in the line once in two seconds. The observer holds in his hand an electric key connected by wires with this pen; as the star passes a line, a quick pressure on the key makes a record on the chronograph sheet. The accompanying illustration shows a chronograph sheet on which has been recorded the transit of a star. Each line is one minute long, *i. e.*, it took the pen one minute to trace it; the regular dashes are just two seconds apart; the eleven irregular breaks are the records made by the observer as the star passed the lines, the middle or sixth being the record made when it passed the meridian line. It will be noticed that opposite one dash the time is marked— $17^h\ 43^m$: from this we may determine the time on any other part of the sheet (as where the star transit is recorded), since progress is made by two-second steps. Such is the method of recording meridian observations at Goodsell Observatory.

The time thus carefully determined is given to the world chiefly through jewelers and railroad companies. From some observatories a constant signal is sent, telegraphing the time day and night; from others, short signals are given at stated hours. The time is telegraphed with extreme accuracy by the clock itself. Wires are run from the telegraph system into the clock, and are so connected with a toothed wheel back of the second hand that the electric current is closed at each even second,—thus producing

the sound of the clock tick on all connected instruments. From Goodsell Observatory the time is sent out twice a day,—at ten o'clock in the morning and at nine in the evening. Any one coming into the clock room at three minutes before ten, would hear the operator at the time desk telegraphing the word "time." This call of "time, time, time," continues for just one minute; it is simply a warning to operators all along the line to stop other business, and have their instruments in readiness for the free passage of the signal. At two minutes of ten, by a change of switches at the table, connections are made with the clock, and for two minutes the clock controls the wires, making itself heard for twelve thousand miles. One unfamiliar with the signal will naturally question how the simple sound of the clock tick can be interpreted so as to give the exact time. Those who receive the signal understand that it begins at two minutes of ten, that just before the beat which marks one minute of ten, there will be a short silence, and that just before the ten o'clock beat, there will be a longer silence. In this way, the meaning of the signal is made perfectly clear.

It is indeed impressive to stand in the presence of the great clock as it sends out its message clear and true, knowing that hundreds of men are listening, setting their clocks and running their trains in obedience to the message of a star.

JUPITER'S FAMILY OF COMETS.

W. W. PAYNE.

In the first number of this journal (p. 25) will be found a brief article on the above named topic. A few errors were made in the names of the comets on the plate accompanying that paper. It is the purpose of this further statement to correct those errors, to add a few more orbits of comets belonging to the family, and to give a table of useful data pertaining to all.

That the reader may easily understand the meaning of the table an explanation of terms commonly used by astronomers to define a comet's orbit is subjoined. We know of none better than that given by Professor William Harkness, of the U. S. Naval Observatory, Washington, D. C., and found in full in the December number of the *Sidereal Messenger*, 1887. We use his explanations with some verbal changes.

When a comet is discovered the first question asked about it is, "What are its elements?" To the vast majority of amateurs these elements are almost unintelligible, and even to adepts they often convey but a vague idea of the orbit. The best way to realize their exact import is by making a model;* and by showing how easily that can be done, it is hoped a fruitful source of instruction and amusement will be brought within the reach of every one interested in the subject.

The orbits of all heavenly bodies are conic sections whose size, form and position in space are defined by six quantities called elements which for brevity are usually designated by the following symbols:

T = Instant of the body's perihelion passage. (By perihelion is meant the nearest point to the Sun in its orbit.)

π = Longitude of the perihelion; in the case of the comet, measured along the ecliptic from the vernal equinox to the comet's ascending node, and thence along the comet's orbit to its perihelion; in the case of the Earth measured along the ecliptic from the vernal equinox to the perihelion.

Ω = Longitude of the ascending node; measured on the ecliptic, from the vernal equinox to the ascending node of the orbit.

i = Inclination of the plane of the orbit to the plane of the ecliptic.

e = Eccentricity of the orbit, sometimes given in parts of the radius and sometimes as an angle φ. Parts of the radius are most convenient for our purpose, and seconds of arc may be reduced to that unit by dividing them by 206,265″. When the angle is given $e = \sin \varphi$.

q = Perihelion distance of the body expressed in terms of the mean radius of the Earth's orbit as unity.

Amateurs will notice that for a parabolic orbit e is unity, and in that case the elements are frequently given by stating T, ω, Ω, i, and log q. Here π has been replaced by

$$\omega = \pi - \Omega.$$

which is counted in the comet's orbit backward from the perihelion to the ascending node, and the perihelion will lie on the northern or southern side of the ecliptic according as ω is less or greater than 180°.

As π and Ω are counted from the vernal equinox, and i is meas-

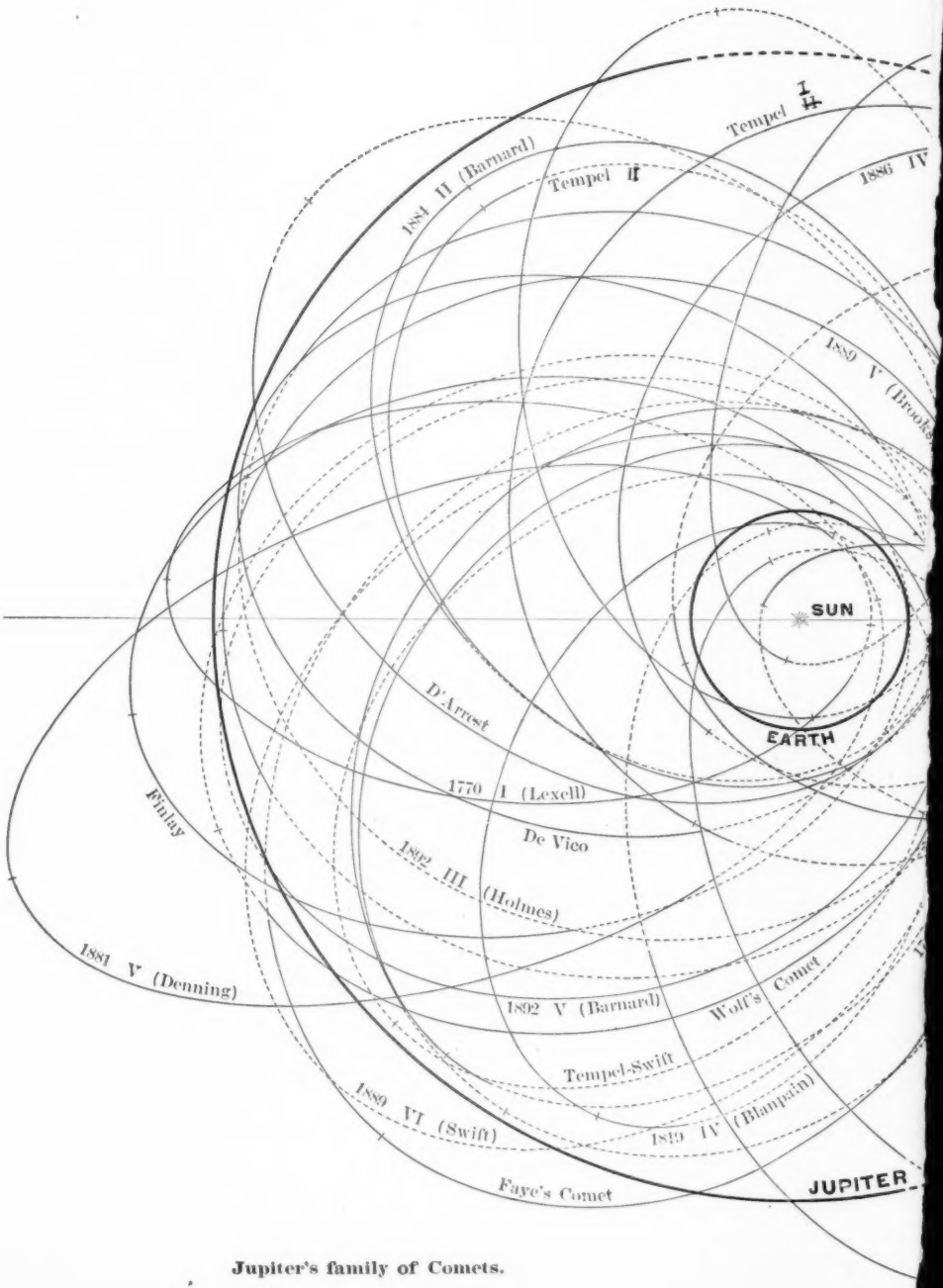
* The mode of doing this is explained in the article referred to.

ured from the plane of the ecliptic, these quantities necessarily refer to a particular equinox which is always specified.

It was long customary to measure longitudes in comet's orbits in the direction of the Earth's motion, to limit i to the first quadrant, and to specify the direction of the comet's motion, whether direct or retrograde; but most astronomers now prefer to follow Gauss in regarding retrograde motion as a result of the inclination passing into the second quadrant, and in accordance with that view they measure a comet's longitude always in the direction of its own motion, and permit i to take any value between 0° and 180°. The circumstance that i is measured at the ascending node limits its range to the first and second quadrants, for if it were to pass into the third or fourth quadrant the ascending node would be converted into a descending one. For a comet having direct motion the numerical values of the elements are the same in the old system as in Gauss' system, but for a comet having retrograde motion they are different, and in that case, if their values according to the old system are designated by a subscript 0, the equations requisite for passing from the old to the Gaussian system are:

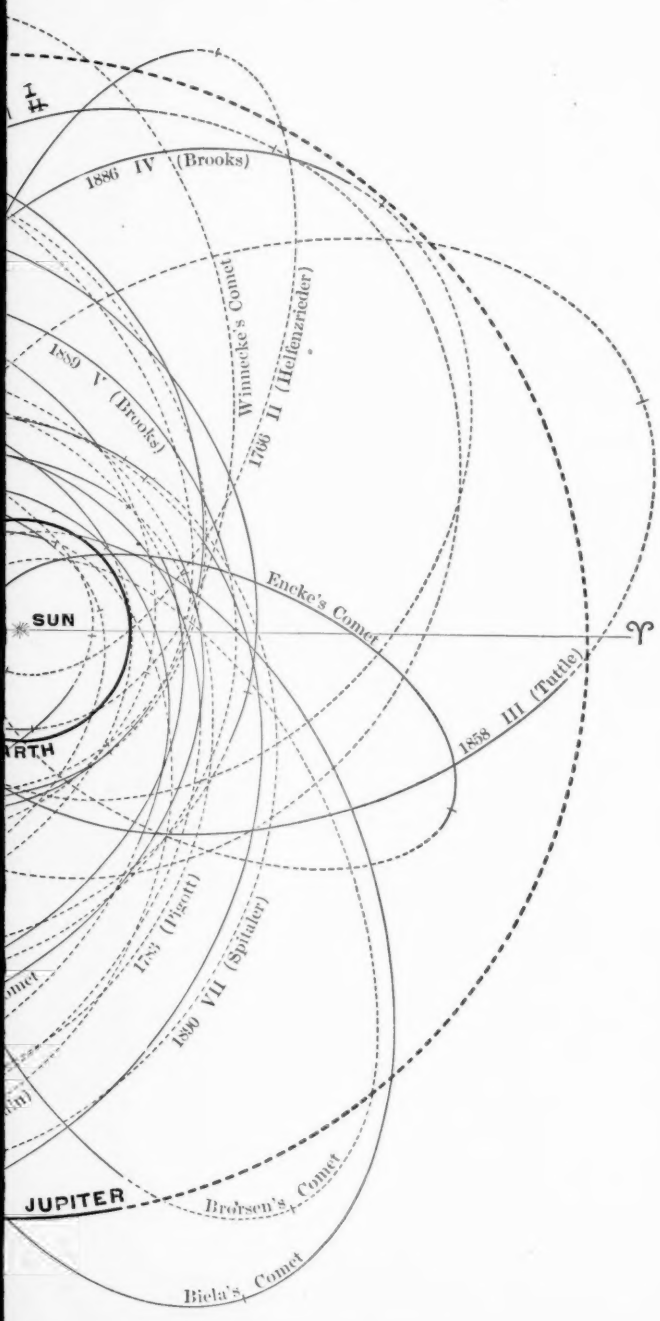
$$i = 180° - i_0 \qquad \omega = 360° - \omega_0 = -\omega_0$$
$$\Omega = \Omega_0 \qquad \pi = 2\Omega_0 - \pi_0$$

There is frequently much confusion respecting the angles π and ω, and as no model can be constructed without using the latter it is important to have a clear understanding of its relations to π and Ω. In the old system of elements π is measured from the vernal equinox, along the ecliptic in the direction of the Earth's motion, to the ascending node of the comet, and thence along the comet's orbit, *still in the direction of the Earth's motion*, to the comet's perihelion. In Gauss' system π is measured from the vernal equinox, along the ecliptic in the direction of the Earth's motion, to the ascending node of the comet and thence along the comet's orbit, *in the direction of the comet's motion* to the comet's perihelion. These definitions may perhaps be elucidated by the following statement: Imagine a perpendicular to the plane of the ecliptic erected from the Sun. Then to an observer situated north of the ecliptic in that perpendicular, the motion of the Earth will be counter-clockwise, and longitudes in the Earth's orbit will increase in that direction. Now consider a comet's orbit, imagine a perpendicular affixed to it in such a way that when the inclination of the orbit to the plane of the ecliptic is i the inclination of the perpendicular shall be $(i + 90°)$, and



Jupiter's family of Comets.

From a drawing by A. G. Sivaslian,
Northfield, Minn.



Goodsell Observatory,
Carleton College.

suppose an observer so situated in the perpendicular that when $i = 0°$ he shall be north of the ecliptic. Then, according to the old system of elements, for all possible values of i the observer will remain north of the ecliptic, and the motion of the comet will appear to him as counter-clockwise when direct, and clockwise when retrograde; but according to Gauss' system of elements, he will be north of the ecliptic when i is less than 90°, south of it when i is greater than 90°, and to him the apparent direction of the comet's motion will always be counter-clockwise. Whichever system is adopted, from his point of view π will always increase counter-clockwise, and to find the intersection of the plane of the comet's orbit with the plane of the ecliptic, or in other words, the line of nodes, he must set off ω clockwise from the perihelion of the orbit."

Under q we spoke of the *mean* radius of the Earth's orbit. By referring to the plate the perihelion and aphelion points of the comet orbits will be readily seen by the short cross-lines at respectively the nearest and farthest points from the Sun. The middle point of the line connecting the perihelion and the aphelion is the center of the curve. The distance from the center to the aphelion or perihelion of the comet's path is called its *mean* distance. The nodes of the orbits are called ascending and descending and are easily distinguished. All the bodies whose paths are represented on the plate move contrary to the hands of a watch. The word "Tuttle" (Comet III, 1858) is near the vernal equinox. Below this word will be noticed the cross-line for the aphelion point in Encke's comet. That point nearly marks the ascending node of the comet path shown by the dotted line becoming continuous. About 180° distant the continuous line is broken, which marks the point of the descending node. From these suggestions it would seem that any popular reader could easily follow all that is said before, if it be remembered how the bodies move, and that the dotted portions of their paths are thought of as being below the plane of the ecliptic and the continuous parts above. It is also believed that anyone will readily understand the following table* which is the most complete one we know of, and is brought down to date.

Our readers will be interested to know that the foregoing description of the "Elements" was so well thought of by C. F. Chambers, author of Chambers' Handbook of Astronomy, (English), as to be used by him in the latest edition of his book which is favorably known everywhere as an authority.

At another time we will give Professor Harkness' rules for making a model of the comet's orbit.

* Elements having no reference are taken from *Annuaire* of 1893, Paris.

ELEMENTS OF THE JUPITER FAMILY OF PERIODIC COMETS.

Comets of which more than one apparition has been observed.

Name.	Period in yrs.	Time of Perihelion Passage.	Perihel'n Distance	Aphelion Distance	e	π	Ω	i	Mean Equinox	Calculator and Reference.
						° ′ ″	° ′ ″	° ′ ″		
Encke	3.303	1891 Oct. 17.986	0.34047	4.09489	0.84647	158 38 46	334 41 27	12 54 58	1891.0	Backlund, Astr. Gesel. J. 27-1
Tempel ♇	5.211	1889 Feb. 2.101	1.38660	4.66545	0.55210	306 08 03	121 09 17	12 45 05	1890.0	Schulhof.
Brorsen	5.456	1890 Feb. 4.104	0.58776	5.61038	0.81034	116 23 10	101 27 34	29 23 48	1890.0	E. Lamp, A. N. 2933.
Tempel-Swift	5.534	1891 Nov. 14.083	1.08660	5.17088	0.65270	43 14 16	296 31 15	5 23 14	1891.0	Bossert, Astr. Gesel. J. 27-1.
Winnecke	5.818	1892 June 30.893	0.88642	5.58313	0.72297	276 11 09	104 04 59	14 31 31	1890.0	Haerdtl, A. N. 3062. Astr. Gesel. J. 28, p. 142
Tempel ♇	6.507	1885 Sept 25.734	2.07332	4.89733	0.40513	241 21 50	72 24 09	10 50 27	1880.0	Gautier, A. N. 2656.
Biela { Nucleus 1	6.587	1852 Sept 23.718	0.86016	6.16732	0.75520	109 05 20	245 49 34	12 33 28	1852.0	D'Arrest, A. N. 933
Biela { Nucleus 2	6.629	1852 Sept 22.952	0.86059	6.19687	0.75512	108 58 17	245 58 29	12 33 50		
Finlay	6.627	1893 July 12.176	0.98912	6.06371	0.71951	7 41 34	52 27 43	3 02 02	1893.0	Schulhof, A. N. 3171
D'Arrest	6.691	1890 Sept 17.493	1.32404	5.77776	0.62713	319 14 34	146 16 32	15 42 41	1890.0	Leveau, Astr. Gesel. J. 26-1
Wolf	6.821	1891 Sept 3.473	1.59285	5.60058	0.55714	19 11 38	206 22 29	25 14 33	1891.0	{ Thraen, A.N. 3050, Berberick, A. J. 253, Astr. Gesel. J. 27-1
Faye	7.566	1881 Jan. 22.671	1.73814	5.97009	0.54902	50 48 47	209 35 25	11 19 40	1880.0	Möller, Berl. Jahrb. 1882

Comets of which only one Apparition has been Observed.

1819 IV, (Blanpain)	4.810	1819 Nov. 20.252	0.89256	4.806	0.68675	67 18 48	77 13 57	9 01 16	1819	Encke.
1766 II, (Helfenzrieder)	5.025	1766 Apr. 26.995	0.39898	5.468	0.86400	251 13 00	74 11 00	8 01 45	1766	Burckhardt.
1884 II, (Barnard)	5.398	1884 Aug. 16.483	1.27969	4.872	0.58395	306 11 20	5 08 38	5 27 33	1884.0	Egbert, A. N. 2657
1844 I, (De Vico)	5.459	1844 Sept 2.484	1.18632	5.015	0.61737	342 30 48	63 49 38	2 54 46	1844	Brünnow.
1886 IV, (Brooks)	5.595	1886 June 6.691	1.32772	4.976	0.57874	230 16 51	53 28 57	12 43 26	1886.0	S. Oppenheim.
1770 I, (Lexell)	5.626	1770 Aug. 13.547	0.67431	5.652	0.78684	356 16 27	131 59 34	1 34 31	1770	Le Verrier.
1783 (Pigott)	5.888	1783 Nov. 19.937	1.45929	5.062	0.55246	50 17 25	55 40 30	45 06 54	1783	C. H. F. Peters.
1892 V, (Barnard)	6.309	1892 Dec. 11.05	1.42911	5.396	0.58123	16 52 36	206 38 45	31 12 28	1892.0	Krueger, Astr. Gesel. J. 28 p. 145
1890 VII, (Spitaler)	6.378	1890 Oct. 26.601	1.81791	5.061	0.47144	58 25 58	45 05 52	12 50 44	1890.0	Spitaler, A. N. 3011
1858 III, (Tuttle)	6.609	1858 May 2.974	1.14922	5.894	0.67368	200 46 27	175 04 09	19 30 02	1858.0	Schulhof.
1892 III, (Holmes)	6.909	1892 June 13.238	2.13940	5.116	0.41024	345 53 12	331 42 12	20 47 23	1892.0	Schulhof, A. N. 3149
1889 V, (Brooks)	7.073	1889 Sept 30.012	1.95023	5.419	0.47070	1 26 17	17 58 45	6 04 10	1890.0	{ Chandler, A. J. 205 A. N. 2952 Astr. Gesel. J. 26 1
1881 V, (Denning)	8.343	1881 Sept 12.834	0.72384	7.503	0.82403	18 10 05	66 09 02	6 53 26	1881.0	Chandler, A. N. 2406
1889 VI, (Swift)	8.534	1889 Nov. 29.572	1.35367	6.998	0.67585	40 15 02	330 36 02	10 14 54	1890.0	Hind, Astr. Gesel. J. 27-1

SHOOTING STARS.

How to Observe Them and What They Teach Us.

W. F. DENNING.

II. Preliminaries of Observation.

To acquire a reliable knowledge of the phenomena exhibited by any class of objects we must accumulate a great number of observations and discuss them in detail. We cannot, from a general view of a subject, or by a merely superficial acquaintance with its observational features, hope to comprehend its real character or to speak with authority as to its scope and various ramifications. It has been customary, in new departments of science, to prematurely draw conclusions and adopt theories on the basis of imperfect data. Meteoric astronomy is not, it is true, a new branch, but its interesting developments are comparatively recent and the state of our knowledge is such that we still need to tread the path leading to further discoveries with the utmost care and circumspection. The great display of Leonids in 1833 may be justly said to have brought the meteoric branch of astronomy prominently into notice, for it not only awakened considerable interest in the subject, but showed the importance of acquiring systematic observations.

The fundamental and really important object in observing shooting stars is to record their *apparent paths* in the sky with exactness. It is also desirable to ascertain their *durations of flight* as nearly as possible, as this element, in the case of a doubly observed meteor, will give the velocity and enable the form of orbit to be determined. "Personal equation" enters very largely into observations of this kind, for the field is one in which errors of judgment cannot be refined by instrumental measures. Indeed it is doubtful if some observers ever attain to the degree of precision which the work essentially requires. Out of say 50 persons not more than one is likely to excel in an extreme degree, and to possess sufficient natural ability and perseverance to allow him to accumulate results of the high character required. This need not however prove discouraging for there is no reason why the most humble observer, whose small beginnings and inadequate methods give little promise of success, should not, by spurring on in the right direction, attain the necessary precision and perform a vast amount of useful work.

Observations of shooting stars are best pursued out of doors,

for the view from a window or opening in an Observatory dome is restricted, and the observer will find that now and then paths are intercepted and lost beyond the limits of his field. Perhaps a flash will suddenly startle him, and although he sees nothing more than that, he realizes having lost a fine meteor. Now this could scarcely have happened had he been observing from an open situation. The writer has often, on seeing a flash, turned in time to catch the end part of the flight, or the streak or train of a brilliant meteor, and has been enabled to record its path satisfactorily though placed in a region of the firmament nearly opposite to that he happened to be watching at the time. In the depth of winter when a starlit sky often means a severe frost, the observer may, however, well be excused for undertaking meteor watches from an open window or some other partially sheltered situation for it is better that he should lose a few paths than relinquish his work entirely owing to the severity of the weather. But it should always be the aim of the observer, if circumstances are propitious, to secure the most commanding place within reach, for the wider the expanse of sky under review the more numerous will meteors appear. It will also be obvious that a good sky must be comparatively free from artificial illumination such as that occasioned by gas or electric light.

A comfortable chair with the back inclined at a suitable angle and with side rests for the arms will be found most convenient for this class of observation. Absolute steadiness and ease in the position of the observer often ensure accuracy in the delicate work of determining the paths. It is the same in this as in some other departments; the more natural and steady the posture of the observer the greater the facility and precision with which the observations will be made. Of course he has to shift to record every meteor seen, but this is not an inconvenience on a cold night, for the frequent movement aids the circulation. In frosty weather I have often found it trying to use the chair at all and generally prefer to pace forward and backward keeping the eyes constantly directed toward the same region in quest of meteors. It is a good plan to lean against a rounded horizontal bar fixed to uprights and about 3½ feet from the ground. This affords a partial rest and enables the observer to maintain his glance upwards for a long time without much inconvenience.

Every meteor that is seen with a fair degree of precision should of course be recorded while all doubtful cases should be rejected. To assist the eye in quickly determining the directions of flight the observer should hold a perfectly straight rod or wand, about 3 feet long, in his hand and project it upon each meteor path as seen,

and then, running his eye along the wand, he can readily note the slope of the track relatively to stars both behind and in front of the line of flight and reproduce it upon his globe or chart. If the eye is left entirely to itself in estimating the directions it will be often found to be an untrustworthy guide, and the wand may be regarded as a necessary corrective; in practice it is certainly found a most efficient aid. The line of flight indicated by it represents an arc in the sky which can be readily penciled upon the globe or chart and the R. A. and Decl. of its initial and terminal points read off and catalogued. The swift meteors which leave streaks are registered with great exactness, for though the motion is so rapid that the nucleus of the object is seen very imperfectly, yet the luminous streak, that lingers for a moment upon the track, affords an unfailing guide to the path traversed. Slow meteors are also to be noted with considerable success, as there is often time to place the wand for them to run apparently along its edge when the positions may be easily noted. The quick meteors, leaving neither streaks nor trains, are recorded with greater difficulty as every visible sign of them is gone before the the wand can be applied. In such cases the observer often receives a correct impression as to the direction and, if he is quick to utilize it, will find that after some practice the radiants of these trainless and transient bodies may be as accurately fixed as those of other classes of meteors.

Different observers employ different means in registering the paths. Some are in favor of star charts, specially constructed for the purpose, while others prefer a celestial globe. The writer has invariably used the latter and found it most effective; the most convenient diameter is one of 18 inches. A disadvantage attached to the globe is that it exhibits the stars in reversed positions to that in which they are displayed in the sky; this is sometimes a source of error and is liable to delay identification of stars in particular cases, but these objections virtually disappear after practice. The paths may be laid on the globe with a soft drawing pencil and after a week or two of observation (during the absence of the Moon) the radiants should be determined and the tracks may then be washed off the globe without injury to its surface.

Star charts are sometimes prefered, but to make these suitable for the purpose a special projection is necessary, for it will be obvious that a straight line upon an ordinary star map will not represent an arc (or meteor path) in the sky. With properly prepared maps (such as those formerly issued by the luminous meteor committee of the British Association or those now in course

of preparation by Mr. Backhouse) there is necessarily great distortion near the edges and, apart from this, there are other drawbacks, for a meteor may be recorded on one map while its radiant lies on another or a long path may have to come in part on two maps. On the whole the globe is decidedly the best means to be adopted, as it represents the entire star-sphere and will include all the paths and radiants of meteors in whatever part of the sky they are visible, and thus prevents the trouble of the multiple references inseparable from the use of star-charts.

The observer must, of course, post the details of every night's observation into a book ruled suitably for the purpose. There is more than one way of doing this, but the simplest is undoubtedly the best. Certain observers have followed the plan of describing the flights according to the stars near, but this method is not to be recommended for general purposes though it serves admirably to indicate the paths of fire-balls when seen casually by a number of different persons. It is, however, less accurate and less definite than the simple and effective plan of giving the right ascension and declination of the beginning and end points of the path. Moreover the work of deducing the radiants of a number of meteors, roughly noted according to approximate stars, cannot be done with anything like the celerity and precision which the other method affords. Let every habitual observer, therefore, follow a uniform plan and register the R. A. and Decl. of every meteor seen. As an example of a catalogue of such observations I quote the following from my results obtained on a clear night in August last:

Ref. No.	Date 1893	Time.	Mag.	Apparent Path.		Length of Path.	Duration.	Notes of appearance.	Probable radiant point.
				From	To				
		h m		R. A. Dec. ° °	R. A. Dec. ° °	°	sec		° °
215	Aug 16.....	12 25	2	10 + 45½	0½ + 39½	9	0.5	Swift, streak.	52 + 57
216	16.....	12 34	3	10 + 14	18½ + 2½	19	1.3	Swift, sparks.	292 + 53
217	16.....	12 47	4	47½ + 59	47½ + 62	3	0.4	Swift, streak.	48 + 44
218	16.....	12 53	4	20 + 40	13 + 34	7	0.4	Swift.	52 + 57
219	16.....	12 56	4	346 + 54½	328 + 58	10½	0.8	Swift.	33 + 18
220	16.....	13 5	1	33 + 26	44 + 12	17½	1.2	Swift, spark.	292 + 53
221	16.....	13 9	3	33¼ + 25	31 + 17	8	0.6	Swift, streak.	52 + 57
222	16.....	13 17	3	21½ + 21½	15½ + 13	10	0.7	Swift, streak.	48 + 44
223	16.....	13 24	3	54 + 29½	63 + 32¾	8	0.8	Rather swift.	33 + 18
224	16.....	13 34	4	19½ + 40	19¾ + 45	5	0.5	Swift, streak.	19 + 29
225	16.....	13 44	3	26 + 63	10 + 63½	7	0.6	Swift, streak.	52 + 57

With reference to the *duration* of meteor flights this is an element which, in the majority of cases, defies exact determination. But it should always be ascertained as correctly as the conditions allow, for it is most desirable to learn the rate of velocity at which these bodies are travelling along their paths. In the case of very rapid meteors our efforts in this direction are baffled by the extreme brevity of the apparitions. The duration is, in fact, so short that any attempt to measure it must result in great uncertainty for the visible life of such bodies extends scarcely beyond the fraction of a second. But the slow-moving class often permit estimates of duration approximating the truth. It is a good plan directly a meteor is seen, to begin counting 1, 2, 3, 4, etc., and to continue until the object disappears; then immediately afterwards to repeat the operation at same rate and to the same figure and determine the interval occupied by reference to a good time-piece. Or the letters of the alphabet may be employed to the same end. The writer became pretty reliable, some years ago, in judging short periods of time by getting a friend to discharge arrows from a bow, while he carefully estimated their time of flight, holding at the same time a second or stop-watch in his hand by which he registered the actual times. Frequent comparisons of the estimated and real intervals and continued practice conduced to greater accuracy, and it was found after numerous trials that the estimates of duration of about 2, 3, or 4 seconds were within about 0.25 sec. of error. By experiences of this nature an observer, though he cannot obtain absolute precision, may at least so far approximate the truth as to impart a value to his results. The necessity for practice in judging short intervals is obvious from the discordant times of duration ascribed by different persons to the same meteor. Instances are on record where the duration has been variously estimated from 2 or 3 seconds to 2 or 3 minutes, and it is well known that individual ideas as to these short periods are remarkably diverse and inconsistent. A little preparation of the character alluded to is, therefore, really needed in order that this significant feature in the observation of meteors may be usefully applied in the determination of their velocities. No doubt the rate of speed is not precisely the same when we see a meteor as it was when the body was outside our atmosphere, for the latter acts as a resisting medium and moderates the velocity; indeed some meteors are observed to "slow up" and to come nearly to a standstill at the end of their flights.

DESCRIPTION OF THE FORTY-FOOT TELESCOPE OF THE LICK OBSERVATORY ECLIPSE EXPEDITION.

J. M. SCHAEBERLE.

In response to a request by the editor for a description of the 40-foot telescope used at the eclipse station, the following details are taken from a "Report" on the Eclipse of April 16, 1893, which I am at present preparing.

The objective lens, made by the Clarks, has a diameter of 4.95 inches. The focal length (photographic) I determined with especial care and found it to be 40 ft. 1.2 inches. The lens forms part of the horizontal photo-heliograph of the Lick Observatory.

In deciding upon the method of mounting, it was entirely out of the question to adopt the ordinary equatorial form in which the tube is suspended near the middle of its length, both on account of the great expense attending the completion of such a plan, and for the still more serious reason of its instability in an exposed position at a high altitude where the atmospheric movements were presumably often quite strong.

Any advantage due to the large scale given by such a telescope would, in a great measure, be lost unless great stability of the image on the photographic plate is secured.

It was not deemed advisable to use the horizontal form of telescope in connection with a plane mirror, as the best possible results which could be given by the lens alone could not be obtained if an intermediate reflecting surface were to be introduced, to say nothing of the effects produced in long exposures by a rotation of the image in position angle with a change in the hour angle of the Sun.

Only one plan was considered feasible, and that was to place the object-glass on one fixed pier, and to mount the photographic plate on a slide (the motion to be regulated, by a clock work, so as to give it the same velocity as the Sun's image in the focus), the guides of which being firmly fastened to a second pier, and both piers to be wholly free from contact with the great tube.

In order to obtain, if possible, coronal features at a distance of several diameters from the Sun, it was decided to use 18×22 inch plates as the diameter of the Moon's image alone would be more than four and one-half inches.

It was, of course, desirable to test the feasibility of putting up such an instrument by actually constructing and erecting it on Mt. Hamilton before leaving for South America.

Fig. 1. Lick Observatory Eclipse Station,
Mina Bronces, Chile, South America,

Fig. 2. Lick Observatory Eclipse Expedition. Forty foot Telescope
April 16, 1893.

The services of our Observatory carpenter, Mr. R. P. Frazer, an unusually expert mechanic, were placed at my disposal by Professor Holden, and in the course of a few weeks, one of the slopes near the summit of Mt. Hamilton was graced with the presence of a rather formidable looking structure which successfully withstood the winter storms for several weeks when it was taken apart and neatly packed for shipment. In designing and constructing the parts, it was of course necessary to know beforehand the approximate geographical position of the eclipse station in order to obtain the proper angle of elevation of the inclined portion of the tube. For this purpose a point on the central line and about 50 miles from the coast of Chile was used as a basis for preliminary computations.

I had at first concluded to occupy the station which Professor Obrecht of the Santiago Observatory had selected, and for which he had previously determined the geographical position, and which was eventually occupied by the Harvard College Observatory party under Pickering. Later on, however, I learned through some published information given by Mr. John King, British Consul at Carrizal Bajo, that by going farther into the interior much higher ground and better atmospheric conditions could be reached, the only unknown elements being the geographical locations.

I finally changed my intended plan of going to Vallenar, and, regardless of the increased number of difficulties to be overcome, determined to locate a station at a great altitude on the central line to be found by personal astronomical observations after I reached Chile.

This change of plan necessitated an early start. On my arrival in Carrizal Bajo, just one month before the eclipse, I was met by Mr. King, and together we spent a week in the interior determining, with the aid of a chronometer and sextant, the astronomical locations of various points, and thus gradually approaching the central line. Finally a most desirable location at Mina Bronces, very near the central line, and at an altitude of 6,600 feet, was selected as offering the best possible advantages. To secure an independent check on the longitude we made a special trip back to Carrizal Bajo, a distance of nearly 100 miles, the transportation being by horseback and railroad. I returned to the station alone, having carried the chronometer in my hands the greater part of a distance of nearly 200 miles.

To detect any possible "tripping" of the chronometer it was frequently compared with other time-pieces during the journey on horseback and train.

A spot of ground was now chosen where the slope was such that only a moderate amount of scaffolding would be required to secure the proper elevation of the tube, and from which the first contact could be observed with the 6-inch Clark equatorial.

To avoid any considerable reflection of light from the inside of the canvas tube it was not only painted a dead black, but the dimensions were made unusually large, being 2 ft. × 2 ft. in cross-section at the objective end and tapering to 4 ft. × 4 ft. near the lower end of the inclined tube, where it joined on to a cubical room whose sides were 6 feet. Small iron rings sewed to the edges of the tube at intervals of a few feet served to secure the canvas to the incircling framework made of uprights 3 × 3 inches and 6 feet long, placed at intervals of 6 feet from each other; the longitudinal and cross-bracing consisted of boards 1 × 3 inches cross-section. The uprights were spliced to conform to the slope of the ground.

At the lower end of the telescope the rock was cut away and an excavation of about two feet in depth made to secure greater stability by lowering the whole telescope. The whole framework was securely held to the Earth by strong wire guy ropes fastened to the top of every upright and running to as many separate iron staples driven into the rock.

The object glass was mounted (with three adjusting screws) in a rectangular slide admitting of a lateral motion of several inches in a frame securely fastened to the end of a vertical rod, which, in turn, could be raised and lowered, and clamped to a strongly braced tripod resting directly upon the ground.

The three legs of this tripod (3 × 3 inches) were set in masonry formed of pieces of rock and a species of mortar called "baro" by the natives. The top of the tripod was a few inches below the lower side of the canvas tube through which the rod passed without direct contact, so arranged, however, that no stray light could enter the tube through this aperture.

After the object-glass was in its final position the whole upper end of the tube, with the exception of an aperture for the objective, was made light-proof by sewing several thicknesses of velvet cloth to the sides of the tube directly in front of the adjusting slide. No vibration of the tube could in any way be communicated to the mounting of the lens and the adjustable parts were in turn protected from the wind by the tube itself.

The cubical room at the lower end of the tube was formed by slipping the already patterned canvas over the framework so that the top and three sides of the cube were completely covered,

the laps of the opening, 4 × 4 feet on the fourth side, were then tacked to the frame which held the lower end of the inclined tube.

The bottom and sides of the excavated parts of the room were plastered with "baro" to prevent the formation of dust as the observers moved about; at the same time great rigidity was given to the lower end of the tube.

Near the extreme end of the room a rather curiously shaped framework* (for holding the angle-iron guides for the triangular slide carrying the sensitive plates) resting on three legs, was also securely fastened to the ground with a liberal supply of "baro."

The frame was, however, first approximately oriented so that the plane of the slide was normal to the axis of the telescope, and the direction of the guides parallel to motion the Sun's image would have on the day of the eclipse. The final adjustments were made by shifting the iron slides on the frame with suitable adjusting screws. Three carefully made wheels, whose axes were fastened to the triangular slide, served to carry the latter.

The two lower wheels had knife edges working in V groove cut in the upper face of the lower guide, the third wheel simply rolled on the planed face of the upper guide. Directly on top of the highest leg the clock portion of one of our chronographs was mounted. The unwinding of a strong flexible wire wound around a drum on the clock's winding axis served to regulate the velocity of descent of the slide to which one extremity of the wire was fastened. The action of gravity on the slide alone was the motive power for running the regulating clock.

The line joining the supports for the photographic plates was made parallel to the line of motion, so that the longer edges of the plates should be parallel to the equator during the exposures.

To insure greater certainty that no diffused light from the outside should find its way through the canvas the whole interior of the room and about 6 ft. of the inclined portion was lined with an extra sheeting of black cloth.

The night before the eclipse each of the eight plates exposed was placed in its own paste-board box, the cover of which could be quickly removed and replaced for the exposures. These boxes were placed in a pile in one corner of the room; in the adjacent corner was a wooden box into which each paste-board box was placed immediately after the exposure of its plate. During totality I was alone in the telescope and there was not the slightest hitch in the program. I only regret that more plates were not made ready for exposure as a number of very interesting phe-

* See Plate No. 5, Fig. 2.

nomena could have been secured several minutes before the total phase. Inside the tube of the great telescope the image of the visual corona extended far beyond the limits of the 18 × 22 inch plates.

I can not close this descriptive paper without making special mention of the services rendered by Mr. Filip Bray, Captain of the mine, and Mr. R. A. Walker, a mechanical engineer temporarily employed at the mine. During the six weeks of my stay every possible aid was given me by Captain Bray. Mr. Walker was ever eager and ready, day or night, to climb the steep trail to the station, only half a mile away, but 260 feet higher up.

During the first week it became apparent that the best photographic results could not be obtained with the filtered water from the mine; the salts held in solution would become visible as a milky substance when combined with the elements used in making the hydrochinone developer.

On mentioning this fact to Mr. Walker, and stating the disirability of having distilled water, he soon discovered (?) a leak in the boiler near the blow-off valve; and thereafter, drop by drop, a bucketfull of water was obtained daily. As this amount proved insufficient later on, when it was also used for a final washing of the plates, Mr. Walker discovered a more serious leak, near the first, the two together furnishing four pails of distilled water daily.

The work done with the other instruments will be fully described in the forthcoming "Report."

LICK OBSERVATORY,
Sept. 11, 1893.

JUPITER'S FIFTH SATELLITE.

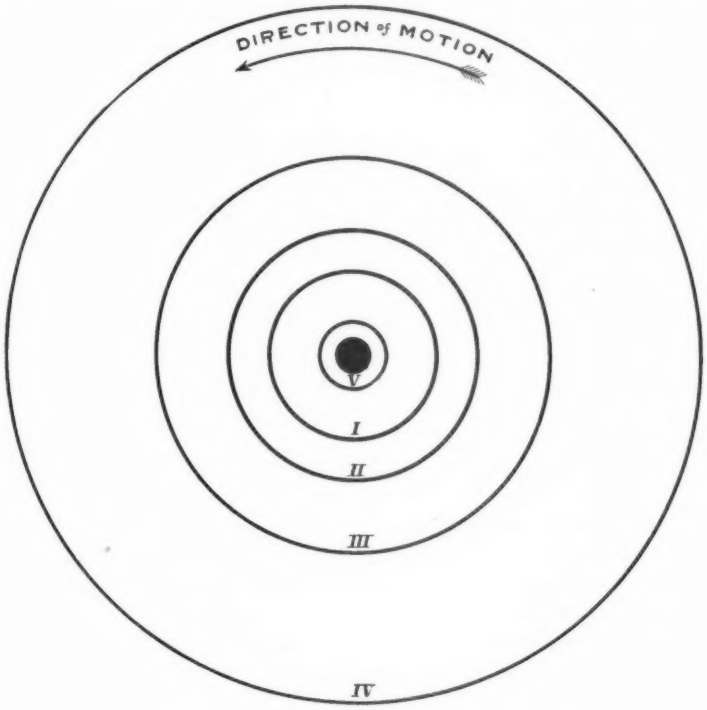
E. E. BARNARD.*

Inasmuch as the discovery of a fifth satellite to the great planet Jupiter on the 9th of September of last year with the large refractor of the Lick Observatory attracted a great deal of popular attention I have thought that now, as this object is again under observation, a little information as to what has become known of it might be of still further interest.

Last winter it was followed with the thirty-six-inch and kept under observation until January 8th, when the increasing distance of Jupiter from us prevented further observation.

* Lick Observatory.

The close coincidence of the satellite period to half a day makes the elongations—the greatest apparent distances of the satellite from the planet, and near which times only is it possible to see it—occur at nearly the same hour of the night for long intervals.



ORBITS OF THE SATELLITE SYSTEM OF JUPITER.

These elongations (on opposite sides of the planet) are six hours apart. In the first part of the summer the western elongation occurred while the planet was yet below or too near the horizon to see a faint object; the other, the eastern, did not occur until after sunrise. These elongations happen essentially five minutes earlier each day. This has gradually brought the morning elongation around so that the satellite can now be seen just before dawn. It was first seen on September 3d, but was too faint to measure satisfactorily. On September 15th, however, it was well seen, and twenty-one measures of its position were obtained. Combining these observations with those of last year it is possi-

ble to very closely determine its period of revolution about Jupiter.

From observations covering only three months I had, last year, determined this period to be 11^h, 57^m, 23.06^s. Dr. A. Marth of the Royal Astronomical Society, using the observations obtained here, had made this period 11^h 57^m 21.88^s. The difference between these results may appear insignificant, but when it is known that the little satellite makes two revolutions around Jupiter every day it will be seen that it counts up in the course of a year, and it was necessary to predict its motion that far in advance. This difference would be nearly two and a half seconds a day, and in a year's time would be a very serious quantity indeed. However, from the short time that the satellite was under observation it was, after all, not so great a discrepancy as one might suppose.

Between the observations at the time of discovery in 1892, until those of this year, the satellite had performed 740 revolutions. With such a large divisor as this, any careful observations now ought to give a very satisfactory determination of the periodic time.

I have again carefully computed its period from the observations of 1892, September 10th, and 1893, September 15th, and the result is: Period, 11^h 57^m 22.56^s, which will perhaps be correct to within a tenth of a second of time.

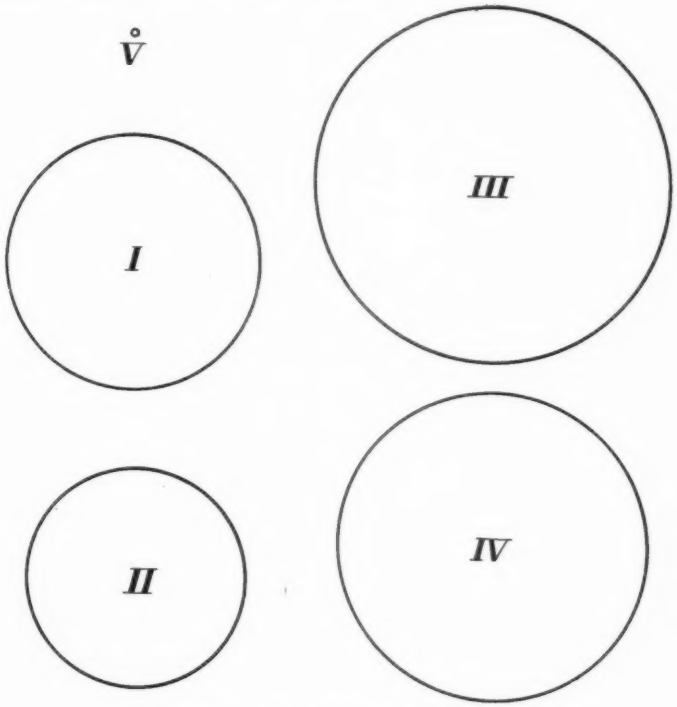
It will be seen that this period is $.50^s$ less than my former determination, and $.68^s$ greater than Marth's result, or almost exactly agreeing with their mean.

From my own measurements I have determined the following facts about the smallest of the Jovian moons:

Its mean distance from the center of Jupiter is 112,000 miles, or about 67,000 miles from the surface of the planet. The orbit seems to be sensibly elliptic, differing somewhat in that respect from the orbits of the other four satellites. This orbit lies in the plane of Jupiter's equator, as do the orbits of the other satellites. The motion of the fifth moon about its primary is 16.4 miles a second, making it the most rapidly revolving satellite known. Though Phobos, the inner satellite of Mars, revolves around that planet in about 7½ hours, yet so great is the circuit of Jupiter's new moon that it actually travels some twelve times swifter than the Martian satellite!

What is its size? This is by far the most difficult thing to determine about it, since it is merely a point and presents no measurable disc. There are, however, several things that tend to limit our maximum estimate of its size.

First—From very careful considerations of the estimate of its brightness I have concluded that if it were seen off on the sky, away from the glare of the planet, it would shine as a star of the thirteenth magnitude. If such is a true estimate of its light, and if its surface has the same reflective capacity as that of Jupiter, it is about one hundred miles in diameter.



Relative Sizes of Jupiter's Satellites.

Second—Under the most favorable conditions and under the highest magnifying power of the thirty-six inch, it has never shown any sensible disc, but appears as a stellar point, while the other satellites readily expand into veritable moons with ordinary telescopic power. If it were much over one hundred miles in diameter it would show a sensible disc with the great telescope.

Third—the most careful scrutiny has so far failed to show any trace of its shadow on the surface of Jupiter, when it should have been projected on the planet. If the satellite were very much above one hundred miles in diameter this shadow would be seen.

The shadows of the other satellites are visible when crossing the planet as large black drops of ink. Hence there seems to be good reason for believing the new satellite to be not much over one hundred miles in diameter; it may be less.

The smallest telescope will show the four old moons—indeed it has been claimed that one or more of these satellites has been seen with the naked eye. Professor George Davidson, in the clear skies of the Sierras, has seen two of them as one with the naked eye when near each other, and at some distance from the planet. This new satellite, however, is game only for the most powerful instruments. So far, since its discovery, it has been reported as seen with the following telescopes: The two 26-inch telescopes at Washington and the University of Virginia; the 23-inch at Princeton, where Professor Young and his assistant, Mr. Read, saw it before the other large telescopes got any observation of it; the 18.5 inch at Evanston, Ill., where Professor Hough saw it and said it was the most difficult of objects. In England Mr. Common saw it with his great 5-foot mirror. Mr. Newhall with the 25-inch telescope at Cambridge, England, saw it and reported it as being an excessively difficult object. For some reason it was not seen on the continent at all. This, so far as I have been able to learn, is a list of all the telescopes that have yet shown the new satellite.

To give one an idea of the relative size of this new moon, compared with the older satellites, it is only necessary to say that the third satellite, the largest of the four, is over twenty thousand times greater than it in volume.

In the May number of ASTRONOMY AND ASTRO-PHYSICS is an interesting article concerning this satellite by Dr. Wilhelm Meyer, of Berlin, who shows that its proximity to the great planet places it in a very dangerous position. It lies just without what is called "Roche's limit," within which a satellite could not exist, as the enormous attraction of Jupiter would tear it to pieces unless its density was greater than that of any known substance.

In the course of his paper, Dr. Meyer says since the diameter of this object is so small, "it is to be concluded with certainty that a freely movable object on the surface of the new Moon must immediately fly away from it towards Jupiter as soon as the latter rises above the horizon. * * * The probabilities are therefore many thousands to one that the new satellite is not able to hold freely movable objects on its surface."

To those who like to people the planets and satellites with inhabitants this will be interesting, for a resident of this little

moon would have to anchor himself pretty fast when Jupiter was visible, or he would very quickly become an inhabitant of the great planet itself!

Dr. Meyer continues: "With the impulse of bodies not held at the surface by molecular forces to fly towards Jupiter will be combined their motion in the orbit of the satellite; the bodies leave the satellite and scatter themselves along the orbit, forming a ring, whose diameter must be less than that of the satellite's orbit and which must resemble in every respect the gauzy, transparent ring which the bright ring of Saturn surrounds. If more and more objects come to it, dust, rock that has crumbled away from the satellite, then the ring will become even denser and finally resemble the bright rings of Saturn. At the outer edge of this ring, the original satellite will continue to revolve and feed the ring with the objects which have deserted it. * * * * This process of crumbling to pieces, working very slowly to be sure, but incessantly, will constantly reach deeper strata as soon as the upper ones are loosened and all fragments are dispersed over the ring. We can therefore maintain to-day, many thousands to one, that the fifth satellite of Jupiter began long ago to form such a ring, and thus Jupiter possesses, at the present time, just as Saturn does, a ring at the distance of this satellite."

He considers, however, that this ring is probably too faint ever to be detected.

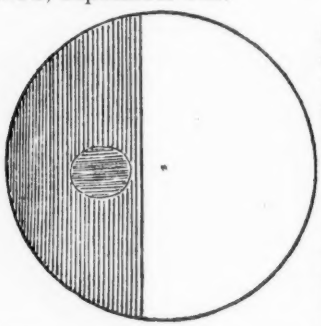
So far this satellite has not received any name, although many names have been suggested for it. Most of these are mythological and have some connection with Jupiter. Columbia, on account of the satellite being found in the Columbian year, and Eureka, because of California, the State in which it was discovered, have been suggested. It would seem, however, almost to have found itself a name—"The Fifth Satellite."

In astronomical literature there is a strong tendency to call it simply "The Fifth Satellite," as it was called in the announcement of discovery. There is some opposition to this, as it might be misleading. The other satellites of the giant planet, besides their mythological names, are also designated as I, II, III, IV, with the Roman numerals, in the order of their distance from Jupiter. If now the new one is called V it would imply that it is the most distant of the satellites, while in reality it is the nearest of all to the planet, and ought by all means, according to this method of numeration, to be Satellite I, which would necessitate a renumbering of the satellite system. I would say, also, in this connection, that the celebrated French astronomer, Camille Flammarion, has written, suggesting the name Amalthea, the

nurse of Jupiter (the smallness of the satellite would make this name rather inappropriate), and giving various reasons why it should be so called.

The most that can be said at present is that it is yet nameless, and may so remain. The mythological names of the four older satellites are seldom used. It may be necessary, however, to give it a mythological name to prevent confusion.

As was the case when Professor Hall discovered the satellites of Mars, many theories have been offered to account for the presence of the new body. The asteroid zone between Mars and Jupiter is an endless source of material for such theories. It was suggested in 1877 that the Martian satellites were asteroids captured by Mars from the asteroid zone lying outside his orbit. These same theorizers have not failed to come up again and suggest that the fifth moon of Jupiter is a captured asteroid from the zone of asteroids lying inside the orbit of Jupiter. They never try to account for the satellites of Saturn, Uranus and Neptune this way, because the asteroid mine is too far off; yet they are similar bodies, and undoubtedly had a similar origin. There is no question that this satellite has been there all along, and for infinite ages has performed its revolutions about the planet, undetected until the night of 1892, September 9th.



So great and overpowering is the brilliancy of Jupiter in the great telescope that it is impossible to see the small moon without extraordinary precautions to get rid of the dazzling light of the planet, as ordinarily the eye is so blinded with the glare that the satellite cannot be seen. With an opaque bar across the field of view, the planet may be hidden and the satellite thus separated from it can be seen. But in measuring the position of the small star-like point it is necessary to see both it and Jupiter at the same time. To make this possible a film of mica, carefully darkened by the smoke of a lamp, is stretched across one-half the field of view. The planet is then placed behind this screen where it can be clearly seen, but with its light greatly dulled, while the satellite is visible in the unobscured part of the field, thus making it possible to see both objects at once.

To illustrate graphically the smallness of the new satellite and to show its position in the Jovian system, I append a couple of diagrams. To those who are familiar with the moons of Jupiter this will show what a tiny speck this little object really is. Compared with Jupiter itself, however, it becomes utterly insignificant, for the great planet is nine hundred times greater than it in diameter, while the volume of the satellite becomes infinitesimally small when contrasted with the enormous bulk of Jupiter.

MT. HAMILTON,
September, 1893.

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD.

The following statements are true for Northfield, Minnesota, October 20, 1893, at 9 P. M. They will be equally serviceable for any other night if it be remembered that for each preceding evening four minutes should be added to the time, and that for each succeeding evening four minutes should be subtracted.

The most striking object in the heavens at this time is the planet Jupiter, two and a half hours above the horizon in the northeast, and shining with a brilliancy five or six times that of the brightest fixed star.

There are five first magnitude stars in view. They are here named in the order of their brightness: Vega (α Lyræ), which four and a half hours ago crossed the meridian at a distance of six degrees from the zenith, twenty years ago sent out the light which reaches us to-night—this is true even though "for every breath you draw light travels half a million of miles." Capella (α Aurigæ, which perhaps should be named before Vega), the most northern of first magnitude stars, is seen in the northeast at a distance of twenty-nine light years. Thus the light which reaches us from Capella is nine years older than that which arrives at the same time from Vega. Altair crossed the meridian thirty-six degrees south of the zenith and more than an hour later than Vega; its distance is sixteen and three-tenths light years. The red Aldebaran (α Tauri) rose toward the north an hour and a quarter ago; its distance is twenty-seven light years. The fifth star is Formalhaut (α Piscis Australis) which some authorities do not class as of first magnitude—it is the most southern of first magnitude stars visible in our latitude, and is just crossing the meridian twenty degrees above the horizon.

Returning to the star Aldebaran, we find it in a rich and familiar region, it being the brightest star in Taurus, and one of the five which make up the lesser group Hyades; this group is rich in doubles and is full of interest for the owners of small glasses. Preceding it by about fifty minutes is the well known closely packed little group Pleiades. The Pleiades afford an interesting test of eye-sight —ordinary vision readily finds six stars, many have seen seven, and one observer is recorded as having seen fourteen; the opera glass greatly increases this number a photograph taken at the Paris Observatory shows two thousand three hundred and twenty-six, the plate covering about three square degrees.

Half way between Aldebaran and the seat of Cassiopeia's chair and a little below the line joining their centres, is the variable star Algol. Algol is usually a second magnitude star but once in two days, forty hours and forty-nine seconds it loses about five-sixths of its light passing from maximum to minimum in about four and a half hours; it remains at minimum twenty minutes. To learn the times of change in October see table on page 41, No. 1, Vol. I. which gives the minima to the nearest hour.

The great nebula of Andromeda may be located by taking as pointers $\varkappa$ and α of Cassiopeia (these are two diagonally opposite stars in the seat, neither being adjacent to the back), and following their line south for about fifteen degrees, when we shall come to a hazy spot which is the brightest of all nebulæ. This is in a more convenient position an hour earlier. An opera-glass does good service if one has no telescope, the nebula is, however, clearly visible to the naked eye. In it appeared the sixth magnitude temporary star of 1885 which a few months later was beyond the reach of even the largest telescopes. γ Andromedæ is one of the most beautiful doubles in the heavens, it may be found fifteen degrees from Algol, on the line joining that star and the Great Nebula, for this star the magnitudes 5.5, 6.8 have been thought probable.

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury will be "evening star" during the greater part of November, coming to greatest eastern elongation, 23° east from the Sun, on the evening of Nov. 5. It will, however, then be at nearly its greatest southern declination, so that it can be seen by northern observers only at a very low altitude. In the southern hemisphere the position of the planet will be favorable for observation during the first half of the month. On Nov. 26, at 6 A. M. Central time, Mercury will be at inferior conjunction with the Sun. The planet will then be 1° 25′ north of the Sun's center.

Venus will also be evening star during November and will be in splendid position for observation from the southern hemisphere of the Earth, but northern observers must content themselves with views at low altitudes. The phase of Venus will be a little more than half full and gradually decreasing, while the apparent diameter of the disk will increase from 18″, Nov. 1, to 24″, Dec. 1. The crescent Moon will pass Venus about noon Nov. 12, so that on that evening and the preceding the two brilliant objects will be near together.

Mars will be morning planet and may be seen in the morning twilight but at so low an altitude that observations will be useless.

Jupiter is the object of objects to be observed by amateur astronomers during November. The planet comes to opposition Nov. 18. It will therefore be visible during the whole night, and as its declination is between 18° and 19° north of the equator, its meridian passage will be at a high altitude. The diameter of Jupiter's disk during this month will be about 47″, so that not only the belts but many small spots and much fine detail on the planet's surface ought to be visible with telescopes of moderate power. No one can mistake this planet, for his splendid brilliancy outshines any other object in the evening sky, with the exception of the Moon. The latter will pass by Jupiter, about 4° to the north, at about 4 o'clock on the morning of Nov. 23. Jupiter's apparent motion will be westward in the constellation Taurus, a little way south of the Pleiades. For the phenomena of the satellites see the tables which follow these notes.

Saturn has just come out from conjunction with the Sun and cannot yet be seen to advantage.

Uranus will be in conjunction with the Sun at midnight Nov. 2.

Neptune is approaching opposition and is at a high northern declination, so that he may be observed under the most favorable circumstances. The trouble with this planet, for amateurs, is that its disk is so small that it cannot be recognized by that with small telescopes, and its motion is so slow that just now it requires two or three days to make the change of position noticeable. In a photograph taken at Goodsell Observatory on the evening of Sept. 21, with the 2½-inch camera, Neptune is on a direct line between the stars i and ε of the constellation Taurus and about one fifth of the distance from the former to the latter star. During October and November the planet will move only 1° 23′ west and 11′ south from its present position. There is but one star as bright as Neptune within a radius of a degree, or twice the Moon's diameter, and that star is toward the north from the planet, so that it is now comparatively easy to identify the planet.

Planet Tables for November.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Nov. 5	16 17.2	− 24 10	8 57 A. M.	1 16.3 P. M.	5 36 P. M.
15	16 44.7	− 24 25	8 45 "	1 04.3 "	5 24 "
25	16 15.1	− 20 33	7 18 "	11 55.4 A. M.	4 33 "

VENUS.

Nov. 5	17 53.6	− 26 11	10 33 A. M.	2 52.2 P. M.	7 01 P. M.
15	18 43.8	− 25 59	10 53 "	3 03.1 "	7 13 "
25	19 31.8	− 24 41	10 55 "	3 11.6 "	7 28 "

MARS.

Nov. 5	13 23.7	− 7 59	4 51 A. M.	10 23.2 A. M.	3 55 P. M.
15	13 48.4	− 10 27	4 47 "	10 08.6 "	3 30 "
25	14 13.7	− 12 48	4 42 "	9 54.4 "	3 06 "

JUPITER.

Nov. 5	3 44.0	+ 18 38	5 20 P. M.	12 41.2 A. M.	8 02 A. M.
15	3 38 6	+ 18 20	4 36 "	11 56.4 P. M.	7 17 "
25	3 33.0	+ 18 03	3 53 "	11 11.5 "	6 30 "

SATURN.

Nov. 5	13 14.1	− 5 24	4 32 A. M.	10 13.6 A. M.	3 56 P. M.
15	13 18.3	− 5 48	3 58 "	9 38.5 "	3 19 "
25	13 22.2	− 6 10	3 24 "	9 03.2 "	2 24 "

URANUS.

Nov. 5	14 35.6	− 14 51	6 32 A. M.	11 34.9 A. M.	4 38 P M.
15	14 38.1	− 15 01	5 56 "	10 58.0 "	4 00 "
25	14 40.4	− 15 12	5 19 "	10 21.1 "	3 23 "

NEPTUNE.

Nov. 5	4 46.7	+ 20 48	6 12 P. M.	1 43.6 A. M.	9 15 A. M.
15	4 45.6	+ 20 46	5 32 "	1 03.2 "	8 34 "
25	4 44.4	+ 20 44	4 52 "	12 22.8 "	7 54 "

THE SUN.

Nov. 5	14 44.4	− 14 56	6 41 A. M.	11 43.7 A. M.	4 47 P. M.
15	15 25.0	− 18 42	6 59 "	11 44.8 "	4 31 "
25	16 06.9	− 20 55	7 12 "	11 47.3 "	4 13 "

Occultations Visible at Washington

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Nov. 14	B.A.C. 7077	6.4	6 22	127	6 56	183	0 34
15	33 Capricorni	5.7	7 05	74	8 19	219	1 14
17	74 Aquarii	6.0	2 14	54	3 23	252	1 09
18	24 Piscium	6.1	11 37	30	12 36	260	0 59
22	τ^2 Arietis	5.3	9 01	125	9 30	173	0 29
24	136 Tauri	5.3	17 51	144	18 30	227	0 39
26	ω^1 Cancri	6.0	13 52	138	14 57	249	1 05

Phenomena of Jupiter's Satellites.

	h	m				
Nov.	2	2	31	A. M.	II	Sh. In.
		3	23	"	II	Tr. In.
		4	51	"	II	Sh. Eg.
		5	38	"	II	Tr. Eg.
	3	5	21	"	I	Ec. Dis.
		7	54	"	I	Oc. Re.
		9	33	P. M.	II	Ec. Dis.
	4	12	32	A. M.	II	Oc. Re.
		2	38	"	I	Sh. In.
		3	01	"	I	Tr. In.
		4	50	"	I	Sh. Eg.
		5	12	"	I	Tr. Eg.
		11	50	P. M.	I	Ec. Dis.
	5	2	20	A. M.	I	Oc. Re.
		6	10	P. M.	II	Sh. Eg.
		6	46	"	II	Tr. Eg.
		9	06	"	I	Sh. In.
		9	27	"	I	Tr. In.
		11	18	"	I	Sh. Eg.
		11	38	"	I	Tr. Eg.
	6	6	19	"	I	Ec. Dis.
		8	46	"	I	Oc. Re.
	7	1	14	A. M.	III	Sh. In.
		2	41	"	III	Tr. In.
		3	01	"	III	Sh. Eg.
		3	56	"	III	Tr. Eg.
		5	47	P. M.	I	Sh. Eg.
		6	04	"	I	Tr. Eg.
	9	5	08	A. M.	II	Sh. In.
		5	38	"	II	Tr. In.
		7	29	"	II	Sh. Eg.
		7	54	"	II	Tr. Eg.
	10	7	16	A. M.	I	Ec. Dis.
		5	22	P. M.	III	Oc. Re.
	11	12	08	A. M.	II	Ec. Dis.
		2	45	"	II	Oc. Re.
		4	32	"	I	Sh. In.
		4	44	"	I	Tr. In.
		6	45	"	I	Sh. Eg.
		6	55	"	I	Tr. Eg.
	12	1	45	"	I	Ec. Dis.
		4	02	"	I	Oc. Re.
		6	27	P. M.	II	Sh. In.
		6	46	"	II	Tr. In.
		8	47	"	II	Sh. Eg.
		9	02	"	II	Tr. Eg.
		11	01	"	I	Sh. In.
		11	10	"	I	Tr. In.
	13	1	13	A. M.	I	Sh. Eg.
		1	21	"	I	Tr. Eg.
		8	14	P. M.	I	Ec. Dis.
		10	30	"	I	Oc. Re.
	14	5	14	A. M.	III	Sh. In.
		5	55	"	III	Tr. In.
		7	01	"	III	Sh. Eg.
Nov.		7	12	A. M.	III	Tr. Eg.
		5	29	P. M.	I	Sh. In.
		5	35	"	I	Tr. In.
		7	42	"	I	Sh. Eg.
		7	46	"	I	Tr. Eg.
	15	4	56	"	I	Oc. Re.
	17	7	10	"	III	Ec. Dis.
		8	43	"	III	Ec. Re.
	18	2	42	A. M.	II	Oc. Dis.
		4	58	"	II	Oc. Re.
		6	27	"	I	Sh. In.
		6	27	"	I	Tr. In.
	19	3	37	"	I	Oc. Dis.
		5	48	"	I	Oc. Re.
		9	01	P. M.	II	Tr. In.
		9	04	"	II	Sh. In.
		11	17	"	II	Tr. Eg.
		11	25	"	II	Sh. Eg.
	20	12	53	A. M.	I	Tr. In.
		12	55	"	I	Sh. In.
		3	04	"	I	Tr. Eg.
		3	08	"	I	Sh. Eg.
		10	03	P. M.	I	Oc. Dis.
	21	12	17	A. M.	I	Ec. Re.
		6	14	P. M.	II	Ec. Re.
		7	19	"	I	Tr. In.
		7	24	"	I	Sh. In.
		9	30	"	I	Tr. Eg.
		9	36	"	I	Sh. Eg.
	22	4	28	"	I	Oc. Re.
		6	45	"	I	Ec. Re.
	24	10	34	"	III	Oc. Dis.
	25	12	44	A. M.	III	Ec. Re.
		4	55	"	II	Oc. Dis.
	26	11	17	P. M.	II	Tr. In.
		11	42	"	II	Sh. In.
	27	1	33	A. M.	II	Tr. Eg.
		2	03	"	II	Sh. Eg.
		2	35	"	I	Tr. In.
		2	50	"	I	Sh. In.
		4	47	"	I	Tr. Eg.
		5	02	"	I	Sh. Eg.
		11	47	P. M.	I	Oc. Dis.
	28	2	12	A. M.	I	Ec. Re.
		6	01	P. M.	II	Oc. Dis.
		8	50	"	II	Ec. Re.
		9	02	"	I	Tr. In.
		9	18	"	I	Sh. In.
		11	13	"	I	Tr. Eg.
		11	31	"	I	Sh. Eg.
	29	6	13	"	I	Oc. Dis.
		8	41	"	I	Ec. Re.
	30	5	39	"	I	Tr. Eg.
		5	59	"	I	Sh. Eg.

In. denotes ingress; Eg. egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow. Only the phenomena visible in the United States are given.

Configuration of Jupiter's Satellites, at 10 p. m. Central Time.

Nov.								Nov.								Nov.							
1			4	3	○	2	1	11			1	○	2	3	4	21		4	3	1	○	2	
2	4	2	3	1	○			12			2	○	1	3	4	22			3	4	○	1	2
3			●	4	○	1	3	13		●	2	○	3	4		23	3	2	1	4	○		
4			4	1	○	2	3	14		3	1	○	2	4		24		●	2	○	1	4	
5			4	2	○	3	2	15			3	○	4	1	2	25			1	○	2	3	4
6			2	4	○	3	1	16	3	4	2	1	○			26				○	2	1	3	4
7			3	1	○	4	2	17			4	2	○	3	1	27			2	1	○	3	4	
8				3	○	2	1	4	18			4	1	○	2	3	28		2	3	○	2	4	
9		2	3	1	○	4		19		2	4	○	1	3		29				3	○	1	2	4
10				2	○	3	1	4	20			4	2	○	3	●	30		3	2	1	○	4	

Phases and Aspects of the Moon.

	Central Time.			
		d	h	m
New Moon	Nov.	8	6	57 A. M.
Apogee	"	11	9	24 P. M.
First Quarter	"	16	11	45 A. M.
Full Moon	"	23	12	08 P. M.
Perigee	"	24	8	00 A. M.
Last Quarter	"	30	3	08 A. M.

Ephemeris of the Fifth Satellite of Jupiter.—We take the following ephemeris by Mr. Marth from the *Monthly Notices* for June, 1893, adapting it to convenient use in the United States. The period of the fifth satellite is assumed to be $11^h\ 57^m\ 21.88^s$, the uncertainty being, according to Mr. Marth, probably within a second of time.

APPROXIMATE TIMES OF GREATEST ELONGATION.

	Greenwich Time.				*Central Time.*			
	East.		West.		West.		East.	
Oct. 5	11	44 P. M.	5	43 A. M.	11	43 P. M.	5	41 A. M.
9	11	22 "	5	21 "	11	21 "	5	20 "
13	11	00 "	4	59 "	10	59 "	4	58 "
17	10	38 "	4	37 "	10	37 "	4	35 "
21	10	15 "	4	14 "	10	14 "	4	13 "
25	9	53 "	3	52 "	9	52 "	3	51 "
29	9	31 "	3	30 "	9	30 "	3	29 "
Nov. 2	9	09 "	3	08 "	9	08 "	3	07 "
6	8	47 "	2	46 "	8	46 "	2	45 "
10	8	24 "	2	23 "	8	23 "	2	22 "
14	8	02 "	2	01 "	8	01 "	2	00 "
18	7	40 "	1	39 "	7	39 "	1	38 "
22	7	18 "	1	17 "	7	17 "	1	16 "
26	6	56 "	12	55 "	6	55 "	12	53 "
30	6	34 "	12	33 "	6	33 "	12	31 "

It will be seen from this ephemeris that the two months of October and November will be very favorable for observations of the satellite, for those who have sufficient optical means. As the times of the satellite's elongations occur at so nearly the same time each night, we have given them only for every fourth night. The others may easily be found by interpolation, the change being five and a third minutes per day. Of course no one will attempt to see this satellite unless he has a telescope of 15 inches or greater aperture.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....0h 52m 32s
Decl.....+81° 17′
Period.....2*d* 11h 50m

Nov. 3	5 P. M.
6	5 A. M.
8	4 P. M.
11	4 A. M.
16	4 "
21	4 "
26	3 "

ALGOL.

R. A.....3h 1m 1s
Decl.....+ 40° 32′
Period.....2*d* 20h 49m

Nov. 2	9 P. M.
5	6 P. M.
8	3 "
17	5 A. M.
20	2 "
22	11 P. M.
25	8 "
28	5 "

λ TAURI.

R. A..... ....3h 54m 35s
Decl.....+ 12° 11′
Period.....3*d* 22h 52m

Nov. 3	1 A. M.
6	midn.
10	11 P. M.
14	10 "
18	9 "
22	8 "
26	6 "
30	5 "

R. CANIS MAJORIS.

R. A..... 7h 14m 30s
Decl..... .....— 16° 11′
Period..... ..1*d* 3h 16m

Nov. 6	1 A. M.
7	4 "
13	midn.
15	3 A. M.
16	6 "
22	2 "
23	5 "

S CANCRI.

R. A..... 8h 37m 39s
Decl.....+ 19° 26′
Period.....9*d* 11h 38m

Nov. 12	6 P. M.
22	6 A. M.

S ANTLIÆ.

R. A..... 9h 27m 30s
Decl.....— 28° 09′
Period..... 7h 47m

Nov. 9	6 A. M.
10	5 "
11	5 "
12	4 "
21	6 "
22	5 "
23	5 "
24	4 "

Asteroids of 1893.—The following table includes all asteroids discovered since the beginning of 1893. The first column gives the temporary designation, each being designated by a *permanent* number later, if sufficient observations are obtained to determine the orbit. Those who have discovered asteroids since the beginning of 1893 are M. Charlois, of Nice, M. Wolf, of Heidelberg, A. Borrelly, of Marseilles.

The total number of asteroids discovered up to January, 1893, was 351. The surprisingly large number already recorded for this year is due to the application of photography to this work, all of these having been discovered by this means:

Designation.	Discoverer.	Date.	Mag.	Designation.	Discoverer.	Date.	Mag.
1893 A	Charlois	Jan. 17	9.	1893 V	Charlois	Mar. 21	13.
B	Wolf	12	13.	W	"	21	12.
C	"	16	13.	X	Wolf	21	12.5
D	Charlois	18	12.5	Y	"	Apr. 14	13.
E	"	20	12.5	Z	Charlois	May 19	12.
F	Wolf	16	13.	AA	"	20	11.
G	Charlois	21	11.5	AB	"	20	13.
J	"	Feb. 11	12.5	AC	"	July 14	12.
K	"	Mar. 8	12.5	AD	"	16	11.
L	"	9	9.	AE	Borrelly	25	12.
M	"	10	13.	AF	Charlois	Aug. 11	12.
N	"	11	12.	AG	"	17	11.
O	"	11	12.	AH	"	19	10.
P	"	11	13.	AJ	"	Sept. 15	12.
Q	Wolf	16	12.	AK	"	18	12.
R	Charlois	17	11.	AL	"	18	11.
S	"	17	12.	AM	"	18	12.
T	"	19	13.	AN	"	20	11.5
U	"	19	13.				

1893 H was found to be identical with 1893 G.

Researches upon Comet 1889 V.—In the last two numbers (302 and 303) of the *Astronomical Journal* Mr. C. L. Poor gives a most interesting paper, entitled, "Researches upon Comet 1889 V." It will be remembered that soon after the first accurate orbits of this comet were computed, Mr. S. C. Chandler called attention to its very close approach to the planet Jupiter and consequent great change of orbit in the year 1886. Mr. Chandler also attempted to roughly trace the comet's previous course and came to the conclusion that this might possibly be the lost Lexell's comet of 1770. Mr. Poor has investigated these questions very carefully, going through an immense amount of calculation, and obtains results which, while they do not confirm the suspicion of identity between the two comets, are of very great importance. In his latest calculations, Mr. Poor used the definitive elements of comet 1889 V, obtained by Dr. Bauschinger from all the published observations, extending over a period of over eight months. There is still some uncertainty in the elements, but taking the most probable values, Mr. Poor, after taking into account the perturbations of all the planets which could perceptibly influence the comet's motion, finds that the comet passed very near to the planet Jupiter in July, 1886, so near in fact as to pass through the satellite system. He says:

"Using the elements for July 20, I find for the perijovian distance of the comet the following, in which the semi-diameter of Jupiter is taken as the unit:

$$q = 2.31 + 0.33\nu$$

[ν being the factor of uncertainty of the elements, and being included within the extreme limits of + 40 and — 40].

"That is, the comet not only passed through the system of Jupiter's satellites, but it actually passed within the orbit of the first satellite, whose mean distance is 5.93 radii of the planet. Taking the extreme limits of ν we are safe in saying that the comet passed the center of Jupiter at a distance of not greater than 3.63, and not less than 1.00 radii of the planet. In other words, the center of the comet may have touched the surface of Jupiter, and it certainly approached that surface to within a distance of 2.63 radii of the planet or only 112,300 miles. Even this latter is a very small quantity.

"For the most probable hypothesis, that of $\nu = 0$, the comet was 2.65 days within the system of Jupiter's satellites, and during this time it made nearly a complete circuit about the planet, passing over an arc of 312° of longitude. The comet entered the Jovian system in longitude 118° on July 18.77, passed the planet July 20.10 at a distance of only 2.28 radii, and July 21.43 left the system in longitude 71°. During this time it must have collided with one or more of the satellites."

Meteors.—Two beautiful meteors were observed here on evenings of August 6th and 11th inst., respectively, both were quite large and somewhat pear shaped. That of the 6th was of a bright green color and travelled swiftly from near ζ Bootes about 15° in a S. W. direction exploding before disappearance a few degrees above the horizon, time 11.03 P. M., central time. The meteor of 11th was of a bluish green color and travelled more slowly from near the 3rd magnitude star 12 Canes Venatici to a point about 10° S.W. of Polaris exploding into numerous reddish sparks. It was so brilliant that the whole landscape was lit up as if by a large arc lamp and was noticed by people even in doors. Time 10.06 P. M., central time. DAVID E. HADDEN.

Alta Iowa, August 17, 1893.

GENERAL NOTES.

We have recovered some of our lost time in publishing the September number so late last month. Our next will be issued about the 5th of November.

Professor J. E. Keeler will give the second article in his series on the Spectroscope in our next number.

S. W. Burnham and **J. A. Brashear** will contribute articles respectively on "Double Star Study" and on the "Making and Care of Telescopes" quite soon.

Dr. L. Swift's illustrated paper on "The Great Nebula of Andromeda," in the series titled "Suggestions to Amateurs" is already in hand. It is an instructive one.

H. C. Wilson's article will interest our readers generally. The frontispiece illustration is a unique one. It is a striking illustration of the apparent motion of the sky. Teachers may use it advantageously.

E. E. Barnard's illustrations of Jupiter's satellites will give definite idea of the new, fifth satellite, which he recently discovered. The finding of that tiny object is said to be the most important Astronomical discovery of the present century.

Miss Mary Proctor, the daughter of the late Professor Richard A. Proctor, is making arrangements to give a series of lectures on astronomy for children all over the country during the coming season. The course consists of three lectures for children, entitled: "The Goblins in Starland," "The Stories of the Stars," and "Giant Sun, and His Family." She will also deliver a lecture said to be specially suitable for Normal Schools, on "How to Teach Astronomy to Children." She delivered these lectures at Chicago, during the World's Fair, and met with success.

Astronomy in High Schools.—A business man in a mechanic association in Boston, not long ago wrote as follows:

It seems to me that a concerted effort should be made by all educators who appreciate the importance of the study of Astronomy, to create a public opinion which should lead to a more general and thorough study of the subject in our High Schools, all over the land. Every town of any considerable size, should have one school armed with a small instrument, properly handled, and the rudiments of Solar Astronomy should be taught to every graduate. It is a burning shame that not one man or woman in one hundred can tell the difference between a planet and a fixed star, neither do they know anything of the path of the planets in the heavens, and look upon the celestial bodies with less interest than they do upon a base ball game, or a new bonnet!

It ought not to be so, and it might be changed if our educators would unite in doing missionary work. But I suppose that they will not, and years must elapse before our boys and girls are told the difference between Venus and Sirius. And we boast of our advanced civilization! Three hundred years ago it was excusable, now it is not. A. B.

Remarkable Sun Spot.—On Sept. 15th, I observed near the eastern limb of the Sun, a large spot which promised to be interesting. On the afternoon of the 17th, the air being remarkably clear and steady, I observed it again. It had increased in size very much since the 15th inst. and in some particulars, is one of the most beautiful and interesting spots I have ever seen. Within an extensive penumbra were nine umbræ intensely black while between two of the largest was an extensive mass of material of a dark red hue, and over a part of another umbra the same reddish matter seemed to be spreading. Between some of the other umbræ the matter was intensely white and brilliant. I thought I detected motion within the spot and watched it closely for some time to assure myself of this fact, but am not satisfied that there was, so as to allege it. I will continue to observe it. The instrument used was my 5-in. Clark refractor with powers of 105 and 200.

It reminds me very much of a spot sketched by Secchi in his *Le Soleil*, in which he shows the red matter or "tail," as he terms it. E. S. MARTIN.

Weighing the Planets.—If we assume the mass of the Earth to be one (1), then the individual and total masses of members of the solar system are as follows:

Sun	= 332,262	Earth	= 1.0
Jupiter	= 317	Venus	= 0.8
Saturn	= 95	Mars	= 0.11
Neptune	= 17.4	Mercury	= 0.06
Uranus	= 14.6	Satellites	= 0.20
		Minor Planets	= 0.25
		Total	332,708.42

For explanation how these results are obtained the reader is referred to Gore's new book entitled *The Visible Universe*, p. 325.

Range of Telescopic Power.—In Young's General Astronomy, page 470 is found a suggestive table showing the relation of the size of telescope to the magnitude of the smallest star visible by its aid. The table follows:

Star Magnitude.	Aperture of Telescope in Inches.	Star Magnitude.	Aperture of Telescope in Inches.
7	0.40	13	6.31
8	0.63	14	10.00
9	1.00	15	15.90
10	1.59	16	25.10
11	2.51	17	39.80
12	3.98	18	63.10

This table assumes that a normal eye and a good telescope, one-inch in aperture will be able to see, as the smallest possible, a ninth magnitude star. On account of the thickness of the largest lenses, the table may fail to give the true relation between aperture and magnitude. Notice how little the gain is in the increase of large apertures so far as magnitude is concerned, but the number of stars in each of these low magnitudes is enormously great. From the above table it also appears that a 20th magnitude star is far beyond any existing telescope.

Variable Stars.—We have been in correspondence with several variable star observers in order to organize a section in this line of observing. Among other letters we have one with a brief working list from Mr. J. A.

Parkhurst of Marengo, Ill. We do not present the list this time, because we wish to accompany it with directions so plain and complete that a beginner may take up the working list and use it regularly. Mr. Parkhurst's letter is so satisfactory that we have asked him to prepare the directions and suggestions that accompany his working lists. All amateurs interested in the observation of variable stars are requested to report to us their names. A description of their telescopes is desired and a statement of work already done, if any.

Miss Mary E. Byrd, Director of the Observatory at Smith College, Northampton, Mass., has prepared and printed a small pamphlet of 39 pages with title, *Questions on the Sky*. It is divided into seven sections with these themes respectively: Sun and Moon; Eclipse of the Moon; Planets for any Year; Planets for the School Year 1893-94; Comets and Shooting Stars; Stars and Milky Way, and Questions for a Telescope with an inch-and-a-half lens.

As introductory the following six rules for observing are given:

1. Begin each night's record on a separate page.
2. Date each page of observations.
3. Record each night the place of observing and the time of beginning and ending.
4. Enter the record in connection with the observation, or immediately afterward.
5. Keep all records of observation in pencil.
6. Make all corrections of the original record and enter copied observations in ink.

In the view of an experienced observer these will seem very common-place directions, and so they are, but no apology is here offered for them because they are elemental in the matter of keeping records. We want to bring just such plain and common sense things to the attention of teachers and young people in the hope that they may gain the benefit of *using* them. Under each section is given a series of questions which form an outline of the theme under consideration, a kind of topical run to guide the student in individual study under the supervision of an instructor. As an illustration we append a few queries from the section on the eclipse of the Moon.

1. Before an eclipse begins can you see any decrease in the brightness of the Moon's limb?
2. At what part of the limb is the shadow first seen?
3. At what instant are you sure that the eclipse has begun?
4. What is the color of the shadow when the moon first enters it?
5. Does the color remain the same throughout the eclipse?
6. An hour after the eclipse has begun what portion of the disc is obscured?
7. At that time what is the shape of the visible Moon?
8. How much does the light of the Moon seen to diminish?
9. What is the form of the line bounding the visible portion of the Moon?
10. Is the bounding line sharp and distinct to the naked eye? Why?

Under the several topics named above the number of questions set range between twenty and one hundred, and the consecutive list above gives a fair idea of the kind of questions chosen. Some such plan as this is very desirable to draw the attention of the student away from a book to the celestial objects themselves whenever this is practicable.

Observatory for Amateurs.—I have read with interest the communications of Messrs. A. E. Douglass (ASTRONOMY AND ASTRO-PHYSICS for March, p. 207), and Charles A. Post (ASTRONOMY AND ASTRO-PHYSICS for May, p. 400), entitled, "The Balance Roof for Telescope Buildings" which has induced me to offer the following description of a modest Observatory I devised and had erected in 1891 to cover my 5-in. Clark refractor. It cost about $80 and has proved secure and very convenient.

The Observatory is built of wood, closely weather boarded, with a stationary roof over one part and a sliding roof over the other part, both covered with tin. Its dimensions are 9 ft. × 12 ft. (the part covered by the sliding roof being 9 ft. × 9 ft.) and 6½ ft. between the floor and cap sills on which the sliding roof rests, the ridge of the roof being 2 ft. above sills. The cap sills on the eastern and western sides of the building project beyond it 4 ft. on the northern and southern sides like arms extended. To the top of each sill is secured, by screws, a semi-circular iron rail ½ in. thick in which the iron wheels, (grooved to fit the rail) travel. Two wheels are secured to each side or gable end of the movable roof on the inside. The wheels (3 in. diameter) and the rails are such as are used for suspending the heavy sliding doors of warehouses and like structures.

The gable ends of the roof, made of solid inch-and-a-half boards, are triangular in shape, 2 ft. in altitude and 9½ ft. base. The upper half of the slant of the roof on each side of the ridge is stationary, being sheathing boards securely fastened to the gable ends and covered with tin. Underneath this part the shutter covering the lower half of the slant of the roof (a light frame covered with tin) slides up, in grooves along the inner side of the gable ends. And in order to have it move easily, small iron rollers or "runners" are placed on the under side of the sliding shutter of the roof and also on the ends as friction rollers.

The shutter being pushed up under the upper part of the roof, as aforesaid, the roof is then rolled by hand pressure to one side until the ridge is vertically over, or beyond the side of the Observatory when an open space is secured ample enough for all movements of the telescope placed in the centre of the building and its declination axis on a level with the cap sills.

To move the roof more easily sash weights (7 lbs. each) are attached to each corner of it by ends moving over pulleys near the ends of cap sills. The roof can be moved towards the north or south, and though rigid and heavy enough not to be affected by strong winds, is yet light enough to be moved with little effort.

The space between the base of the roof and the cap sills on which it moves is covered by a weather strip of wood, extending below the top of the cap sills, which also serves as a guide to keep the roof in position when in motion.

The view around the horizon is unobstructed by the roof, except at a very low altitude above the north or south point, towards which it may be moved. In practice I always roll it towards the north which permits an unobstructed view of the heavens, except a small portion about the northern horizon.

When the roof is to be moved, the telescope is placed in a horizontal position, the declination axis being also horizontal, which permits the roof to pass at a safe distance above it.

In the above sketch details have been ignored and only the main features presented with the hope that it may be understood and at least suggestive.

Wilmington, N. C. E. S. MARTIN.

Occultation of Antares by the Moon.—The occultation of Antares by the Moon was observed here on the night of July 23 and was a most beautiful sight.

The atmosphere was clear and steady and definition remarkably good. The brilliant crimson star touched the Moon at the top of the eastern side, or range of a large crater (near the southern point of the Moon) which appeared as an isolated line of light, separated from the illuminated body of the Moon by a dark space, (the bottom of the crater) and by dark gaps at both ends. Along this uneven line of light Antares glided, its glowing crimson contrasting most beautifully with the brilliant white light of the mountain side, upon which it apparently rested until the star reached a point near its southern end, when it instantly disappeared as if it had plunged into the dark gap. At emersion it as instantly reappeared. The dark limb of the Moon was not seen. The instrument used was a 5-inch (Clark) refractor with power 105. E. S. MARTIN.

Richard A. Proctor's memory in America fell quickly into sad neglect, if the dilapidated condition of his tomb in Greenwood Cemetery, Brooklyn, N. Y., for the last few years is a proper evidence of public forgetfulness of one deservedly so well known previously in the home of his adopted country. It is a blessing to ours, or any country, to have such men in it as George W. Childs of Philadelphia, whose generous impulses are always alert to repair humiliating neglect or public injustice like this which sometimes overtakes the good and the honored of this world. It is doubtless known to most of our readers that Mr. Proctor died of yellow fever in a New York hospital, a day or two after his arrival from Florida, his home. None of his family were present, and because of the fever immediate burial was uncessary, and the place chosen was the vacant lot in Greenwood cemetery owned by the undertaker. Through Mr. Child's thoughtful generosity the mortal remains of this eminent man were given an honorable burial and a simple though beautiful monument in their new resting place. We pay his memory a just tribute in the well chosen words of another:

"While the astronomer was an Englishman, the most active and useful years of his career were passed in America. Original and thorough as were his researches in many fields of science, it was as a lecturer and a writer that he chiefly distinguished himself. It was in America that his talent of scientific exposition was most highly appreciated and developed. It was here that his best work was done as a popular lecturer, with a lucid and animated style and a remarkable power of interesting audiences in his scientific studies. So marked were his usefulness and success here as a public educator that America had become his adopted home. His grave is where it ought to be, in one of the loveliest corners of Greenwood, with many famous men whom he knew in life at rest around him. Henceforth it will not be an unmarked, neglected grave."

Popular Astronomy in Africa.—We are just in receipt of a postal card with the reply card attached asking what will be the expense of postage on this publication to Cape Town, Cape Colony, Africa, from which the card was mailed, as that district is not in the postal union. It is also asked if it is our intention to give the current celestial phenomena for the southern hemisphere as well as those of the northern. Truly the astronomical world is becoming one in its intercourse in many ways.

Queries Pertaining to Astronomical Themes.—We have known for some time that amateurs have desired a general corner, through which to secure information that might be given by questions and answers. We will try hereafter to give attention to requests of this kind and furnish answers to them as fully and promptly as possible. Correspondents and readers are respectfully asked freely to share in this to make the plan generally useful.

1. What months of ASTRONOMY AND ASTRO-PHYSICS have most in them about the Total Solar Eclipse of April 16, 1893? W. W. B.

Answer: February, April and October. The first gives an account of the predictions of the corona made by Professor F. Bigelow, Washington, D. C., according to his magnetic theory, so-called, with a fine frontispiece illustration. The second gives some account of the path of the line of totality across South America and Africa indicating the most available stations on the two continents and some notice where different observing parties were intending to be located. In this number three large cuts are given to show definitely what is described in the text. In the last issue of ASTRONOMY AND ASTRO-PHYSICS will be found two articles by Professor Schaeberle of Lick Observatory. In one he states the preliminary results of his work at the Lick Observatory station in Chile which he thinks fairly accord with his theory of the corona known generally by the name of the "Mechanical Theory," an illustration of which will be found in the January issue, 1893. In the other will be found his reply to the criticisms of astronomers in England and America who claim that the photographs obtained at the different stations along the line of totality do not show a fulfillment of the predictions of his theory. In the October number will be found a beautiful photogravure plate of the Solar Eclipse as observed in South America by Professor Schaeberle. Short exposure only was given to bring out the detail of the inner corona. In the November number of ASTRONOMY AND ASTRO-PHYSICS, 1893, will appear a companion plate showing the corona as it could be photographed by longer exposure to bring out the exterior corona more fully. In another place in this number of *Popular Astronomy* is given an illustration of the 40-foot telescope used in obtaining these pictures and also a general view of the station in South America occupied by Professor Schaeberle to observe this eclipse.

2. Are the rising and the setting of the heavenly bodies the same in Eastern time as in Central? M. B. T. H.

3. In the case of phenomena that do not depend on the rotation of the Earth, as the minima of Algol, is the longitude of the place necessarily considered? M. B. T. H.

4. Given a 4-inch telescope, so good that it will easily resolve α Scorpii, or α Lyræ with a power of 95, and will separate π Aquilæ (1″.7), or ε Arietis (1″.3) with a power of 180 on any good night. If the above aperture be cut down to 2 inches by an annular diaphragm it will resolve Rigel with a power of 95. If a stop be applied cutting out the central 2 inches, the glass will resolve Rigel with difficulty. A central stop cutting out $2\frac{3}{4}$ inches, but exposing a margin of more than twice the area of the first central 2 inches will fail to resolve Rigel. Do all good objectives suffer in a like degree from uncorrected spherical aberration? The above experiment seems to indicate that the central 2 inches of a 4-inch glass will resolve more than a whole 3-inch objective, especially on a bright object. S. G. S.

5. What are the practical difficulties in the way of better eye-pieces? Do not our expert opticians prefer to temper the objective to the eye-piece rather

than to attack the latter and attempt to improve it? The negative eye-piece is fair, but is it not much behind objectives in perfection? S. G. S.

6. There is a faint star in Cassiopeia not far from $\varkappa$, the location of Tycho's Nova, as given by Dr. Klein which I have been watching for a week, and can find nothing to correspond with it in Klein's map and D'Arrest's chart. Is it not worth the while of observers to examine it? Its position roughly is 30′ right ascension and 63° 20′ declination. D. F.

BOOK NOTICE.

Elementary Mathematical Astronomy, with Examples and Examination Papers. By C. W. C. Barlow, M. A. B. Sc., and G. H. Bryan, M. A., London. Clive & Co., University Correspondence Press, Warehouse 13 Booksellers Row Strand, W. C., 1893, pp. 493.

On the amateur side of our study there are doubtless many of our readers who desire to know of just such a new book as this which is just received from the publishers. This book, although first published in 1892, has already passed through its second edition. Its introductory chapter is on spherical geometry. Then follows the celestial sphere with the definitions and an explanation of the motions of bodies on it. Thirty pages are given to this theme, followed by twelve examples and an examination paper with ten questions.

The next chapter is devoted to the Observatory in which the principles of the common observatory instruments are explained and fully illustrated, and the work they are intended to do shown. Examples on this theme follow and an examination paper. In the first part of the book there are eleven such chapters. The titles besides those named are The Sun's Apparent Motion in the Ecliptic; Time; Atmospheric Refraction and Twilight; Determination of position on the Earth; The Moon; Eclipses; The Planets; The Distances of the Sun and Stars.

Under the division of Dynamical Astronomy three chapters more are given. The rotation of the Earth; The Law of Universal Gravitation and Future Applications of that Law; then follow a series of useful notes, an appendix, answers to examination questions and a full index.

The book is on the plan of the University extension study and is certainly a useful one to give accurate and independent ideas in the study of Astronomy by the aid of elementary mathematics. It is intended for amateurs, and its form is useful for faithful self-instruction, which is part of the plan of a correspondence college. It also furnishes a series of good tests for the student as he advances, by the examples and the examination papers given in connection with each topic.

Publisher's Notices.— The subscription price for POPULAR ASTRONOMY is $2.50 per year, foreign countries 14 shilling, payable in advance, the annual volume consisting of ten numbers, issued monthly, except for July and August, each containing at least 48 pages of reading matter. Articles for publication may be sent to Wm. W. Payne, Goodsell Observatory, Carleton College, Northfield, Minn., or to Miss C. R. Willard, same address. All remittances for subscription or advertising should be sent to Miss Willard who is in charge of the accounts of the office.

Please take notice that all payments of dues should be made in post office orders or notes, or bank drafts on Chicago, New York, St. Paul or Minneapolis. Personal checks are banked at a discount.

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